

MONTHLY
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CORRECTION

REVIEW, April, 1927:

Page 169, second column, fourth line from bottom, "1925" should be "1926."

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INTERNATIONAL AEROLOGICAL SOUNDINGS AT ROYAL CENTER, IND., MAY, 1926

PART I. INTRODUCTION

By W. R. GREGG

Meteorologists generally will be glad to learn of the resumption of sounding-balloon observations in the United States. Several series were made prior to 1915, some of these being at St. Louis, Mo., by the Blue Hill Observatory and others at Omaha, Nebr., Huron, S. Dak., Indianapolis, Ind., and Avalon, Calif., by the Weather Bureau. Much valuable information was obtained in these series, but there are still lacking certain data which would be most useful both in theoretical and practical meteorology. For example, the characteristics of the atmosphere at great heights above anticyclones and cyclones in this country are not known in any great detail. There is reason to believe that they differ in important respects from those in Europe, but more data are needed to establish these differences. Other questions concerning which comparatively little is known at these extreme upper levels are the seasonal, latitudinal, and diurnal variations of the different meteorological elements.

The series at Royal Center, Ind., during May, 1926, is the first of what is hoped to be a large number, each one covering a month or more, and some of them consisting of simultaneous soundings from several points, for the purpose of investigating conditions at wide intervals of latitude or in different parts of high and low pressure systems.

In general these series are planned in accordance with the program of the International Commission for the Exploration of the Upper Air, formerly known as the International Commission for Scientific Aeronautics. Prior to 1925 it was the custom of this commission to select certain isolated days, usually one in each month, but in some cases three, and in one month each year a group of six days in succession. At the April, 1925, meeting of the commission the Weather Bureau proposed that all effort be concentrated in one month each year. In this way, at the end of 12 years, there would be as much observational material as under the previous plan, the entire year would be covered (assuming a different month were selected for each of the 12 years) and, most important of all, these data would give information regarding day-to-day changes almost entirely lacking now. This proposal was adopted, not as a substitute but as an addition to the previous program, and May, 1926, was named as the first "international month."

In addition to the work with sounding balloons during this month, the Weather Bureau collected a large amount of observational material regarding upper clouds. A study of these data will be published at a later time.

Moreover, special upper air observations were made at all kite and balloon stations, in order to have as complete information as possible in all parts of the country. Copies of these data and of those procured with sounding balloons have been forwarded to the International Commission for publication with similar data from other countries.

The results of the sounding balloon campaign at Royal Center are given in the two papers following—that by

Mr. Fergusson describing the methods and instrumental apparatus employed, and the one by Mr. Samuels discussing the data themselves.

A series of sounding-balloon observations similar to that at Royal Center in 1926 will be made at Groesbeck, Tex., in October, which has been named the "international month" for 1927.

PART II. INSTRUMENTS AND TECHNIQUE

By S. P. FERGUSON

The International Series of aerological soundings at Royal Center afforded opportunity for the trial of three new devices for facilitating the exploration of the atmosphere, namely, the light meteorograph and accessories designed in 1919 for use with *ballons-sondes*, the Rossby deflating valve, and an adaptation of the meteorograph to Assmann's method of the free-rising captive balloon.

METEOROGRAPHS AND ACCESSORIES

The design of the meteorograph, first described in the MONTHLY WEATHER REVIEW for June, 1920, 48:317-322, was based upon experience derived from the use of earlier apparatus by Assmann, Teisserenc de Bort, and Richard. Distinctive features are simplified construction permitting economical production in quantities, a two-traverse mechanism recording pressure on a scale twice that of earlier instruments and a single time-arc for all elements which simplifies the work of reading records. The temperature-element, of thin thermostatic metal, and the hygrometer, the hairs of which are separated, are more sensitive than similar elements in use previously and permit a very rapid rate of ascent and descent—a feature of great importance at stations near large bodies of water where ascensions must be completed within a short period. The very small weight (only one-third that of the lightest time-recording instrument in use previously) permits the use of molded pilot-balloons having an initial diameter of 30 to 50 centimeters expanded to about 130 centimeters before release.

Standardization of the meteorographs was accomplished easily and rapidly by means of the improved low-pressure-low-temperature apparatus designed by Messrs. H. J. E. Reid and Otto E. Kirchner of the Langley Memorial Aeronautical Laboratory who kindly permitted the construction of a duplicate in the instrument laboratory of the Weather Bureau. In this apparatus the conditions of pressure and temperature during a high ascension are duplicated and it is possible to standardize six instruments simultaneously. Evaluations of the scales before and after ascensions were in close agreement and the performance of the Bourdon-tube pressure-elements was particularly good.

The meteorograph is protected from accidental injury by surrounding it with three hoops or buffers 30 centimeters in diameter, of rattan, secured by four threads to the corners of a piece of bright red silk about 1 meter square, which serves as a parachute and also to attract the attention of a possible finder.

BALLOONS

Data of the four types of balloons used are given in Table 1, below.

TABLE 1.—Molded balloons used at Royal Center

Average initial diameter	Average weight	Expanded for ascension diameter	Excess lift	Number necessary
Cm.	Grams	Cm.	Grams	
38	120	105	488	2
38	220	105	388	2
23	78	75	270	3
16	30	60	85	5

Larger molded balloons are not manufactured in America, and preliminary tests having shown that inflation of the 38-centimeter balloon beyond 110 centimeters was unsafe it became necessary to use two for each ascension in order to secure a free lift exceeding 500 grams. Premature explosion during inflation reduced the number available so far that, to secure the required number of ascensions, smaller balloons were used in combination with the larger during some ascensions and alone during the last 10.

TECHNIQUE OF ASCENSIONS OF BALLONS-SONDES

The technique of the ascensions at Royal Center followed closely that of earlier work in Europe and America described in detail in the *Annals of Harvard College Observatory*, Vol. 68, part 1, with the chief exception that pure compressed hydrogen was used instead of gas generated chemically as was the case at St. Louis.

Before every ascension the meteorograph was examined and adjusted with extreme care, particularly the pivots of recording mechanisms and the clocks which were oiled with kerosene to reduce friction to a minimum and avoid losses of records. The usual comparisons with a standard psychrometer were obtained at the last moment before ascension, while both instruments were exposed in air well stirred by a ventilating fan. Whenever possible the altitude and azimuth of the ascending balloons were observed every minute by means of a theodolite at one station and during some ascensions simultaneously at two stations 1,782 and 1,983 meters apart to obtain the direction and velocity as well as independent measures of height.

Summary.—The performance of the new equipment can best be estimated by comparing the 44 ascensions at Royal Center with the 21 ascensions at St. Louis in May, 1906, of Assmann balloons carrying meteorographs and accessories developed by Teisserenc de Bort at Trappes. The latter series was conducted by the writer.

TABLE 2.—Comparison of ascensions with old and new equipment

	St. Louis, May, 1906	Royal Center, May, 1926
Balloons, inflated for ascension:		
Number and diameter.....cm.	(1) 175	(*) 105
Weight.....grams	1,500	250 and 340
Parachute, weight of.....do.	425	25
Basket, etc., weight of.....do.	115	40
Meteorograph, weight of.....do.	400	175
Total weight, balloons and accessories.....grams	2,440	490 or 580
Excess lift.....grams	500	700 or 630
Greatest height attained.....meters	16,500	17,200
Average maximum height (meters):		
All ascensions (number and height).....(20)	10,090	(36) 10,690
First 34 ascensions.....		11,240
12 ascensions (best balloons).....		11,700
Last 10 (small balloons).....		9,250
Cost:		
Meteorograph.....(1905) \$50	(1920) \$110	
Accessories.....(1905) 10	(1920) 2	
Balloons.....(1905) 17	(1920) 8.50	
Total, corrected to 1925.....	150	129

Probably there should be some allowance for the use, at St. Louis, of chemically generated gas, which, though dried, may have been inferior to that used at Royal Center. Fourteen of the first 34 ascensions at Royal Center were made with one 38-centimeter and one 23-centimeter balloon each, and the last 10 with five 15-centimeter balloons each, the lift of which was insufficient for high ascensions. The "best balloons" (Table 2) are 38 centimeters in diameter and weigh 120 grams, hence have a lift proportionately greater than that of heavier balloons of the same capacity.

The meteorograph and accessories were very satisfactory; there were a few instances of defective pressure records due to unsteadiness of balloons and minor defects of construction very easily avoided hereafter, and one clock stopped during part of an ascension. The pressure marker is controlled by gravity during its first traverse of the record sheet and the occasional violent jerking of two loosely secured balloons during some ascensions caused a decided widening of the traces on the upper side. This condition does not occur when one balloon is used, and was remedied by tying the balloons together so that they moved as one. It will be desirable, however, to alter the mechanism to prevent free motion of the marker if this can be done without increase of weight and cost. Further simplification of the technique of preparation of apparatus for use is highly desirable but can not be assured at present.

Since 1920 the price of the new meteorograph has advanced to \$140, but that of balloons seems to be decreasing, and exploration with the new equipment continues to be less costly than with the larger, heavier apparatus formerly in use. As shown by the last 12 at Royal Center, high ascensions, occasionally to the stratosphere, can be obtained with pilot balloons 23 and 15 centimeters in diameter, at a cost of only about \$2.25 for the number required, but the rate of ascent of a number of balloons is smaller than that of a single balloon having the same lift, consequently the ventilation is more than likely to be insufficient for ascensions during the daytime and, moreover, the apparatus may be carried long distances before it reaches ground.

Obviously, the height attainable by a rubber balloon will depend largely upon the range of expansion, which is retarded by cooling of the gas during the ascent, and limited by loss of elasticity that occurs when rubber is exposed to low temperatures. The 38-centimeter balloon will expand to about 200 centimeters before explosion or twice the diameter when inflated for ascension; that this allowance for expansion is insufficient is indicated by the fact that the maximum height at Royal Center was only 5,500 meters above the average maximum attained by the best balloons while at St. Louis the excess was 6,410 meters, and that the average diameter of inflated balloons at the beginning of the 11 highest and 5 lowest ascensions was 102.8 and 104.6 centimeters, respectively. However, the number of ascensions was too small and the quality of the balloons too variable to establish a standard of inflation.

All data available confirmed earlier conclusions, that the greatest and the highest average maximum heights and the most rapid rates of ascent and descent will be attained by the use, during each ascension, of a single large, light balloon having sufficient free lift, without preliminary expansion, to carry the lightest procurable meteorograph and accessories. For the highest ascensions it will probably be necessary to use the Dines meteorograph weighing 28 grams instead of the heavier time-recording instrument used at Royal Center.

Recently (1927) excellent sheet-rubber balloons 77 to 150 centimeters in diameter, weighing 680 to 2,400 grams and costing \$5 to \$17.50, have become available and tests thereof are in progress, the results of which so far, are encouraging. However, in view of the superiority of spherical molded balloons, large sizes of which are difficult to manufacture and not now procurable in America, it is desired to interest manufacturers in experimenting with cylindrical or other forms possibly more economical to produce and having greater capacity than the 38-centimeter balloon whose limitations have been discussed.

THE ROSSBY DEFLATING VALVE

The purpose of this device, invented by Dr. C.-G. Rossby, of Sweden, is the deflation of balloons at any predetermined time after ascension begins so they may be used repeatedly and the cost of exploration with *ballons-sondes* thereby materially reduced. A valve in the neck of the balloon is kept closed by an elastic cord until the latter is burned through by a fuse timed for the period and height desired. At Royal Center two of these valves constructed and tried under Doctor Rossby's supervision functioned perfectly during all trials at various heights up to 1,500 meters. In August three of five ascensions by the Hobbs expedition to Greenland were successful, deflation occurring as timed, at 500, 800, and 1,800 meters, respectively. The two failures during ascensions timed for greater heights were probably due to obstruction of the valve by water condensed from the gas which was generated from calcium hydrid and not thoroughly dry.

From these experiments it appears that the height attainable when this device is used will depend chiefly upon the weight of the fuse and the rate of ascent. The valve used at Royal Center weighed 70 grams, the fuse 40 grams per meter, and the rate of burning was 40 centimeters per minute; consequently, if the usual ascensional rate of 160 to 200 meters a minute is maintained, the maximum height attainable should be between 3,500 and 5,500 meters. A large free lift will be necessary if very high limited ascensions are desired.

Dr. J. E. Church, jr., of the University of Nevada, who aided in the ascensions in Greenland, suggests that greater certainty of action and improved efficiency can be secured by the use of three or four balloons, preferably the 23-centimeter size, all but one of which are exploded by the fuse, the remaining balloon serving as a parachute. This experiment has not been tried.

THE FREE-RISING CAPTIVE BALLOON

(1) If a captive balloon pulls out its line from a controlled reel the height attained will depend largely upon the wind, the pressure of which drives the balloon downward. (2) If the line is reeled out so rapidly that the only restraint is the increasing weight the balloon will move with the wind, rising freely until the weight equals the free lift, and attain a greater height than will the brake-controlled balloon. Since 1904, using one to three rubberized silk balloons having a capacity of 20 cubic meters each, flown with the wire and reel employed at other times in kiteflying, the German Aeronautical Observatory at Lindenburg has achieved very remarkable results by means of the second method. A maximum height of 6,000 meters has been reached with three balloons and the average maximum during one year is about 3,000 meters. Usually a high ascension is accomplished within an hour, and very satisfactory

ascensions have been secured when the velocity of the wind exceeded 5 meters a second; the highest velocity during an ascension was 10 meters a second. Since, to reach a height of 5,000 meters a balloon of rigid materials (rubberized silk) must be able to rise when half inflated, it follows that, as is the case with *ballons-sondes*, a rubber balloon should be more efficient as a captive than the rigid one. In a discussion published in 1909 Assmann advised a large rubber balloon having one-half the capacity of the one made of rubberized silk, and evidently the smaller ones used as *ballons-sondes* were employed to some extent, particularly by the German expedition to East Africa in 1907, which carried 12,000 meters of 0.3 mm. music wire for use as line, but comparisons of the two types of balloons are not available. This improved method is so superior to that of the ordinary captive balloon that a descriptive name is desirable; accordingly, I have suggested the compounds "free-rising captive" which is self-explanatory, or "free-captive" which, though not so definite, is shorter and indicates the distinctive feature with sufficient clearness.

Since the free lift of the 38-centimeter balloon already described is practically the same as that of the larger, heavier ones employed by Assmann, it appeared probable that the former might prove to be satisfactory used as a free-captive; accordingly, a plan for an experimental trial was offered by the writer in September, 1925. In our discussions of this application of new equipment fear was expressed that the line of very small music wire would be very difficult to manage, but a preliminary trial was authorized during the international series at Royal Center. The reel and other equipment improvised for the occasion were not very suitable for such an experiment, but the results, even under these unfavorable circumstances, were very encouraging. The highest of the three ascensions (to 1,200 meters, reached with 1,700 meters of No. 2 wire) required only 24 minutes, during which period the velocity of the wind varied between 1 and 4 meters a second. When reeling in began one of the two balloons exploded but the other fell so slowly that the line rested on the ground only a few minutes, probably because of a temporary descending wind. The balloons were much steadier than kites and the line gave no trouble whatever; at no time was there a slackening sufficient to cause loops, although the pull never exceeded 1 kilogram.

The most important factor in exploration by this method is the vertical movement of the balloon, which, in order to maintain adequate ventilation of the meteorograph on clear days, should not fall much below 150 meters a minute. The rate of ascent is highest as the balloon leaves ground, decreasing as the weight of wire increases until the greatest height is reached; up to this point the balloon has moved with the wind, which does not affect the height. When reeling in begins, the wind, combined with the speed of reeling, drives the balloon downward at a rate that is greatest at the beginning of the descent. Therefore by utilizing records during ascent and descent, when the rate approximates 150 meters a minute, it should be possible during most ascensions to secure accurate data at all heights up to the maximum. The maximum height can be computed from data of the free lift and surface of the balloons, the velocity of the wind, and weight of wire; the size or strength of wire desirable to use will depend upon the highest wind likely to occur during an ascension. For example, assuming that the balloon is to be used chiefly when the wind is too light for kites (below 4 or 5 meters

a second) and that the pressure of wind upon a sphere is about one-half that on a normally exposed plane having the same surface, the total pressure on a balloon 150 centimeters in diameter in a 5-meter wind will be 1.62 kilograms at sea level, or about one-fourth of the safe working strain of a No. 00 wire (the smallest music wire manufactured). The pressure of the wind on the line is negligible; probably not more than one-sixth that on a normally exposed flat plate whose surface is equal to that of the line, or about 0.2 kilogram on 5,000 meters of No. 00 wire in a 5-meter wind.

All data available, including the experiments at Royal Center and a very obvious one of suspending short lengths freely without strain, show conclusively that, compared with larger wires used in kiteflying, the smallest music wires are far more easily controlled, and injurious bends, loops, and "kinks" more easily prevented. It is probable that most instances of kinking occur after wire under strain has been drawn over some object (a branch of a tree or corner of a building) small or sharp enough to cause permanent bends which form loops whenever tension slackens. It is possible that small wires are more easily weakened by rust than are the larger sizes, but a protective covering of oil is easily applied to wire on the storage drum.

The data in Table 3 will be useful if wires and balloons larger than those described herein are considered desirable.

TABLE 3.—Data of music wire useful in aerological exploration

Music-wire gauge number	Diameter		Weight of 1,000 meters	Ultimate tensile strength
	Mm.	Inch	Kilograms	Kilograms
00	0.20	0.008	0.29	10
0	0.22	0.009	0.33	14
1	0.25	0.010	0.40	17
2	0.27	0.011	0.49	21
3	0.30	0.012	0.59	26
4	0.34	0.013	0.69	31
5	0.37	0.014	0.84	37
6	0.42	0.016	1.05	44
7	0.46	0.018	1.32	52
8	0.50	0.020	1.63	61
9	0.55	0.022	1.95	74
10	0.61	0.024	2.25	85
11	0.66	0.026	2.60	97
12	0.71	0.028	3.08	113
13	0.76	0.030	3.56	126
14	0.81	0.032	4.00	140
15	0.86	0.034	4.52	148
16	0.91	0.036	5.00	162
17	0.97	0.038	5.71	178
18	1.02	0.040	6.37	189
19	1.07	0.042	6.94	203
20	1.12	0.044	7.46	223
21	1.17	0.046	8.33	236
22	1.22	0.048	9.09	256
23	1.29	0.051	10.00	281
24	1.40	0.055	11.48	311
25	1.50	0.059	13.51	350
26	1.60	0.063	15.63	402
27	1.70	0.067	17.84	450
28	1.80	0.071	20.00	533
29	1.88	0.074	22.22	590
30	1.98	0.078	24.39	657

In consequence of slight variations in diameter the weights and tensile strengths of different lots of wire are likely to vary 5 per cent or more from the values stated, and specimens from the same piece will sometimes vary in strength 2 per cent or more. Also deterioration with use causes a gradual reduction of strength. Accumulated experience indicates that the working strain ordinarily should not exceed two-thirds of the ultimate tensile strength.

The following suggestions are offered regarding equipment and technique for future use of this method:

Reel.—The storage drum recommended is a light, two-flanged cast-iron pulley of standard design, the diameter and face of which, respectively, are 422 and 100 millimeters (17.5 and 4 inches); the circumference is so nearly 1.4 meters that the error of registration, of a counter geared direct to the axis, will be about 1 per cent; therefore negligible for the small wire used. The drum may be operated by hand or power, but if by power a quick-acting reversing gear should be provided so that, with the motor running continuously, the speed and direction of winding are at all times under control and can be reversed instantly in emergency. One simple device of this kind consists of two belts, preferably round, one straight and the other crossed, connecting the drum with the motor. These belts are loose but may be tightened alternately by means of a single lever carrying two loose pulleys bearing on the belts. The drum, motor, etc., should be mounted in a light box or frame that can easily be rotated about a vertical shaft to allow for changes in the direction of the wind. The speed of winding will depend upon the size and free lift of the balloons and probably should be at least 300 meters a minute. The pull or strain will always be too small to operate guide pulleys or separate counting mechanisms and the line must be wound directly on or from the drum without touching anything.

Since, as already stated, the line must be reeled out as rapidly as the balloon rises and kept approximately horizontal at the ground, the reel can be operated most efficiently if it is placed on a roof or tower with free exposure in all directions; the line then can be kept above near-by trees, etc., and the maximum height easily ascertained.

Meteorograph and accessories.—The small meteorograph already described is easily modified for use with the captive balloon by substituting ink pens and ruled paper for the markers and metallic record sheets used during very high ascensions. Since the heights at present are not likely to exceed 5,000 or 6,000 meters it will be advisable to widen the scales of temperature and pressure, the former to 1 millimeter for 1° C. and the latter to a range of 6,000 meters for the width of the record sheet. The exposure of the thermometer and hygrometer may require improvement to insure proper ventilation on clear days. The basket and parachute may prove to be unnecessary, but are advisable at least when wind and weather are unfavorable for ascensions.

NEPHOSCOPES AND OBSERVATIONS OF CLOUDS

Observations several times daily of the heights and motions of clouds formed an important part of the aerological program of May, 1926, and at Royal Center provided information regarding the nephoscope and accessories issued to stations in 1921. The nephoscope proper (a mirror in a circular frame graduated to 5° of azimuth and resting on three short legs) probably is amply satisfactory, and the separate eyepiece and its support, with slight changes, should also be considered satisfactory; but, in the interests of efficiency and the convenience of the observers, the installation or location and methods of use should be changed wherever this is possible. When the nephoscope was designed uniformity of installation was emphasized, and since, at nearly all stations, the instrument could be placed on a roof the support approved consisted of a large iron plate supported by an iron column fixed in a heavy block of concrete resting on leveling screws. The nephoscope and accessories are kept on this stand and

protected from the weather by a copper cover detachably secured to the stand by means of bayonet joints.

At Royal Center the nephoscope is some 50 meters distant from the nearest building, and, apart from this inconvenience, observations often are prevented or seriously interfered with by wind that disturbs the eyepiece and index, rain that blurs the mirror, and the various outdoor noises that prevent hearing the timing clock. The bayonet joints in the soft metal of the cover bent and broke after a short period of use and other means of security against wind and rain became necessary. These conditions of exposure doubtless exist to some extent at most stations and, together with certain deficiencies of design and construction, can easily be corrected, as follows:

Nephoscope.—For the greatest convenience of operation the nephoscope should be self-contained; i. e., the mirror and eyepiece together mounted on a short tripod stand. The eyepiece should be on a swinging arm in two or three jointed sections for convenience in observing through a wide range of altitude. The outdoor stand may be retained for emergencies when conditions are unusual, but wherever the windows of an office or observatory provide good visibility it will be most convenient, particularly in stormy weather, to place the nephoscope on a window sill where observations can be made with ease and in comfort. Proper leveling and orientation are secured by attaching to window sills on different sides of a room an iron plate having sockets for the legs of the nephoscope; such plates are inexpensive and easily installed in any convenient place indoors or outdoors, and since the nephoscope is removed to the room after use a cover will not be needed. If the separate eyepiece and stand are retained the horizontal sliding arm (difficult to adjust) should be replaced by a pivoted, swinging arm in two sections.

Timing clock.—The small clock now used for timing relative velocities should be replaced by a watch, preferably one with an eight-day movement, beating 240 times a minute, held to the observer's ear by the springs of an ordinary head telephone. Almost any watch will do for timing if the frequency of beat is allowed for, but one beating 240 times a minute will be most convenient. The Ingersoll watches are very satisfactory for this purpose; also, observations indoors can be timed by the clock of the "triple register."

Long experience with many instruments used in measuring clouds indicates that, with very simple apparatus, used when conditions are comfortable, accurate and valuable observations require no more effort or time than poor or unsatisfactory observations or estimates without the aid of instruments. It should be unnecessary to repeat here the fact, obvious to all students, that, considering time, cost, and effort, observations of clouds yield more information concerning the upper atmosphere than any other method of exploration.

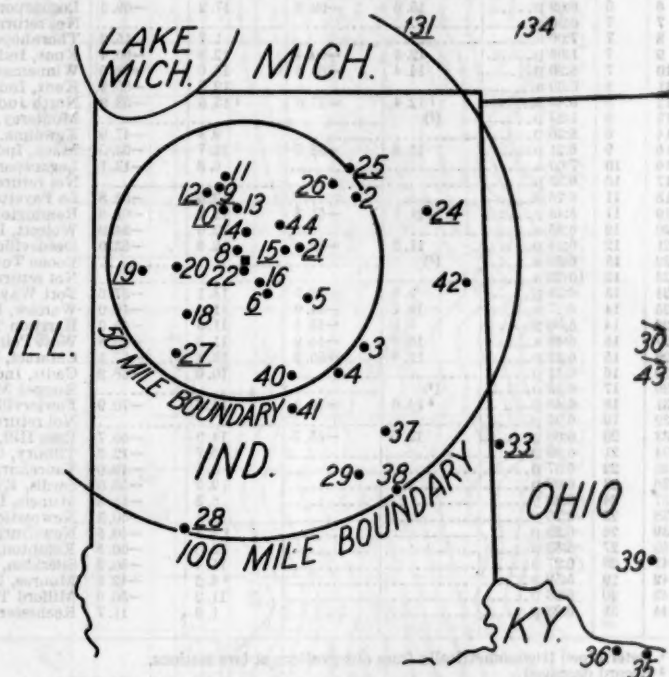
The nephoscope is a simple instrument which has been drawn across the temperature curves in Figure 2 in order to give an indication of the relative variation in the altitude of these isothermal surfaces. It is evident that the changes in temperature from day to day are as great as it is not greater, at 10 km. than they are at the lower levels of 2 to 4 km. Figure 3 shows the pressure isobars over Royal Center during the month. The altitude of the base of the stratosphere is indicated by the letter "S." There will be noted a period of change in this elevation. From a maximum height on the 6th there is a general lowering to a minimum on the 14th followed by a rise to a maximum on the 16th.

PART III. THE RESULTS OF THE ASCENSIONS

By L. T. SAMUELS

A total of 44 soundings was made during the month, of which 39 instruments have been returned. Table 4 contains general information concerning the individual observations.

In Figure 1 are shown the landing places of the balloons, the numerals indicating the serial number of the observation. Fifty-six per cent of the returned instruments landed within 50 miles of Royal Center and 80



LANDING PLACES OF SOUNDING BALLOONS SENT UP FROM ROYAL CENTER, IND. MAY 1926

FIG. 1

per cent within 100 miles. The greatest distance an instrument was found was 425 miles, this one having fallen on a mountain peak in Pennsylvania. The distance away an instrument falls, however, is not always a reliable indication of the height reached, owing to superposed opposing winds. For example, the greatest height during the series was reached on the 6th although this instrument fell only 11 miles away, having traveled in a southerly wind in the lower levels and a northerly wind in the higher levels.

In three cases the records were returned damaged, making it impossible to determine what height these reached. Fourteen of the records showed the instruments to have reached the stratosphere.

As is usually found, the altitude of the base of the stratosphere fluctuates considerably. In general it was high over high pressure, particularly over the rear of high pressure and low over low pressure and likewise particularly over the rear of low pressure. This relationship is in agreement with the results of earlier sound-

TABLE 4.—Summary of the observations

Serial number of ascent	May, 1926	Time of ascent 90th meridian	Stratosphere		Maximum height above mean sea level	Minimum temperature	Meteorograph found—		Balloons		
			Height of base above mean sea level	Temperature, at base			Place	Distance and direction from Royal Center	Number used	Initial diameter of each	Net free lift
			Km.	°C.	Km.	°C.		Km.		Cm.	Grams
1	1	6:34 p.					Not returned		2	38	980
2	2	6:20 p.			7.7	-27.6	Piercetown, Ind.	76, ne.	2	38 and 23	528
3	3	6:18 p.			5.3	-16.4	Fairmont, Ind.	57, se.	2	38	683
4	4	6:11 p.			8.2	-31.5	Elwood, Ind.	55, se.	2	38	685
5	5	6:06 p.			12.0	-64.6	Peru, Ind.	59, ese.	2	38	694
6	6	6:09 p.	15.8	-69.3	17.2	-69.3	Logansport, Ind.	18, se.	2	38	831
7	7	6:50 a.					Not returned		2	38	715
8	7	7:06 a.			1.7	-15.2	Thornhope, Ind.	8, nw.	2	38	554
9	7	1:06 p.	12.3	-60.4	12.8	-60.4	Knox, Ind.	45, nnw.	2	38	616
10	7	6:20 p.	14.4	-68.6	15.6	-68.6	Winnemac, Ind.	32, nnw.	2	38	679
11	6	6:30 a.			12.7	-65.2	Knox, Ind.	50, nnw.	2	38	645
12	6	6:45 a.	11.2	-57.0	13.0	-58.9	North Judson, Ind.	43, nw.	2	38	641
13	8	1:27 p.	(¹)		9.3	-47.9	Monterey, Ind.	31, nnw.	2	38	844
14	8	6:20 p.			13.7	-53.5	Kewanna, Ind.	18, n.	2	38	713
15	9	6:21 p.	11.6	-63.5	6.8	-13.1	Macy, Ind.	26, ene.	2	38	730
16	10	7:03 a.					Logansport, Ind.	13, se.	2	38	638
17	10	6:25 p.			12.5	-62.8	Not returned		2	38	743
18	11	6:25 a.			13.1	-61.8	La Fayette, Ind.	45, sw.	2	38	739
19	11	5:43 p.	11.5	-61.8	12.0	-54.9	Remington, Ind.	61, w.	2	38	700
20	12	6:35 a.			12.6	-63.0	Wolcott, Ind.	39, w.	2	38	600
21	12	6:15 p.	11.3	-63.0			Deedsville, Ind.	34, ene.	2	38	705
22	13	6:39 a.	(²)				Boone Township, Ind.	3, s.	2	38	375
23	13	10:25 a.			13.1	-57.6	Not returned		2	38 and 23	330
24	13	6:23 p.	9.8	-53.9	11.4	-46.0	Fort Wayne, Ind.	113, ene.	2	38 and 23	330
25	14	6:27 a.	10.1	-44.9	11.5	-45.0	Warsaw, Ind.	76, ne.	2	38 and 23	255
26	14	5:30 p.	8.9	-44.5	11.9	-50.8	Harrison Township, Ind.	69, ne.	2	38 and 23	375
27	15	6:48 a.	10.0	-46.9	13.1	-57.5	West Point, Ind.	68, sw.	2	38 and 23	343
28	15	6:32 p.	11.8	-56.9	10.6	-58.2	Catact, Ind.	161, asw.	2	38 and 23	250
29	16	6:41 p.	(³)		14.6	-70.9	Cadiz, Ind.	130, se.	2	38 and 23	330
30	17	6:33 p.			14.0	-65.7	Rugged Mountain, Pa.	684, ese.	2	38 and 23	280
31	18	6:43 p.	14.6	-70.9	5.7	-12.6	Fowlerville, Mich.	242, ne.	2	38 and 23	350
32	19	6:23 p.			4.3	-40.5	Not returned		3	23	479
33	20	6:08 p.	13.6	-65.7	9.9	-50.0	Rose Hill, Ohio	177, se.	3	23	235
34	21	6:39 p.			5.8	-11.8	Tilbury, Ont.	322, ne.	2	38 and 23	305
35	22	6:37 p.			11.1	-50.3	Vanceburg, Ky.	343, se.	5	15	270
36	22	6:09 p.			13.0	-60.5	Sardis, Ky.	306, se.	5	15	255
37	24	6:33 p.			11.4	-50.9	Muncie, Ind.	117, se.	5	15	238
38	25	6:25 p.			11.2	-50.6	Newcastle, Ind.	142, se.	5	15	195
39	26	6:20 p.			11.9	-51.7	New Burlington, Ohio	257, se.	5	15	185
40	27	5:53 p.			11.2	-50.6	Kempton, Ind.	72, ese.	5	15	200
41	28	6:27 p.			11.7	-51.7	Sheridan, Ind.	90, ese.	5	15	
42	29	5:59 p.					Monroe, Ind.	134, e.	5	15	
43	30	6:25 p.					Millford Township, Ohio	322, ese.	5	15	
44	31	6:23 p.					Rochester, Ind.	29, ne.	5	15	

¹ Determined trigonometrically from observations at two stations.

² Record damaged.

³ Heights above 9 km. based upon mean rate of ascent.

⁴ Pressure element failed above this height; from an estimate based on the minimum temperatures these heights were as follows, No. 35, 10,700 meters, Nos. 39 and 42, 9,500 meters.

An unusually large proportion of the instruments were found to the west of the station. The first group of these occurred on the 7th and 8th (Nos. 8 to 14) when this region was under the influence of a "saddle"; i. e., a high-pressure area to the north and south and low pressure to the east and west, when deep southeasterly winds prevailed; the second group occurred on the 11th and 12th (Nos. 18 to 20) when the station was on the front side of an extensive high-pressure area covering the entire western part of this country and Canada and deep easterly winds prevailed; the third group occurred on the 15th (Nos. 27 and 28) when Royal Center was between a low to the east and a high to the west with upper winds northeasterly.

The lowest temperature recorded during the series was -70.9°C. , at 14.6 kms. on the 18th. This has been exceeded on two previous occasions on this continent, viz, at St. Louis on January 25, 1905, when -79.4°C. was recorded at 14.8 kms., and at Woodstock, Ont., on November 5, 1913, when -74.5°C. was recorded at 12.4 kms.

Figure 2 shows the vertical temperature gradients for the individual observations. The temperatures in $^{\circ}\text{C.}$ are shown for the surface, the highest altitude and the base of the stratosphere. The wind directions have been included wherever these were observed.

As is usually found, the altitude of the base of the stratosphere fluctuated considerably. In general, it was high over high pressure, particularly over the rear of high pressure and low over low pressure and likewise, particularly over the rear of low pressure. This relationship is in agreement with the results of earlier sound-

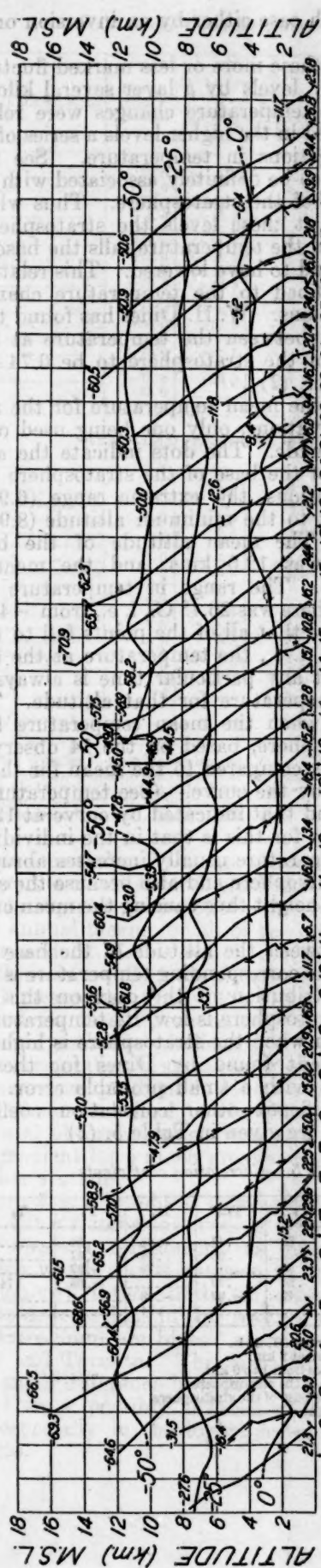
ing balloon observations made in this country (1) and elsewhere (2).

The maximum altitude of the base of the stratosphere (15.8 kms.) for the series was observed on the 6th when the station was on the western side of a high-pressure area. The lowest altitude (8.9 kms.) was observed on the 14th, at which time the station was on the western side of a low-pressure area.

The fluctuation in the altitude of the base of the stratosphere during relatively short periods is clearly indicated in Figure 2. Thus, on the 7th it was 12.3 kms. at 1.06 p. m. and 14.4 kms. at 6.20 p. m., showing a change of 2.1 kms. in 5 hours on the 14th it was 10.1 kms. at 6.27 a. m. and 8.9 kms. at 5.30 p. m., changing 1.2 kms. in 12 hours, and during the following 12 hours it again rose to 10.0 kms.

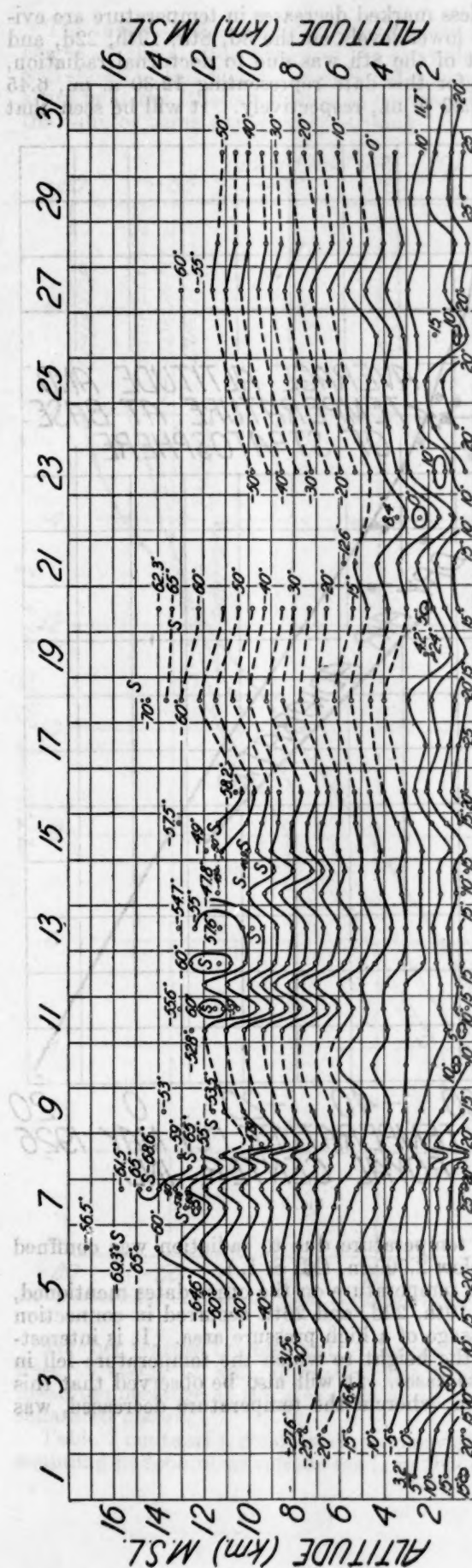
The isotherms for 0°C. , -25°C. , and -50°C. have been drawn across the temperature curves in Figure 2 in order to give an indication of the relative variation in the altitude of these isothermal surfaces. It is evident that the changes in temperature from day to day are as great, if not greater, at 10 kms. than they are at the lower levels of 2 to 4 kms.

Figure 3 shows the free-air isotherms over Royal Center during the month. The altitude of the base of the stratosphere is indicated by the letter "S." There will be noted a periodic change in this elevation. Thus from a maximum height on the 6th there is a general lowering to a minimum on the 14th followed by a rise to a maximum on the 18th.



VERTICAL TEMPERATURE GRADIENTS AS OBSERVED AT ROYAL CENTER IND. MAY 1926

Fig. 2



FREE AIR ISOTHERMS OVER ROYAL CENTER, IND., MAY 1926

Fig. 3

More or less marked decreases in temperature are evident in the lower levels on the 3d, 8th, 19th, 22d, and 26th. That of the 8th was due to nocturnal radiation, the records for this date representing 12.30 a. m., 6.45 a. m. and 6.20 p. m., respectively. It will be seen that

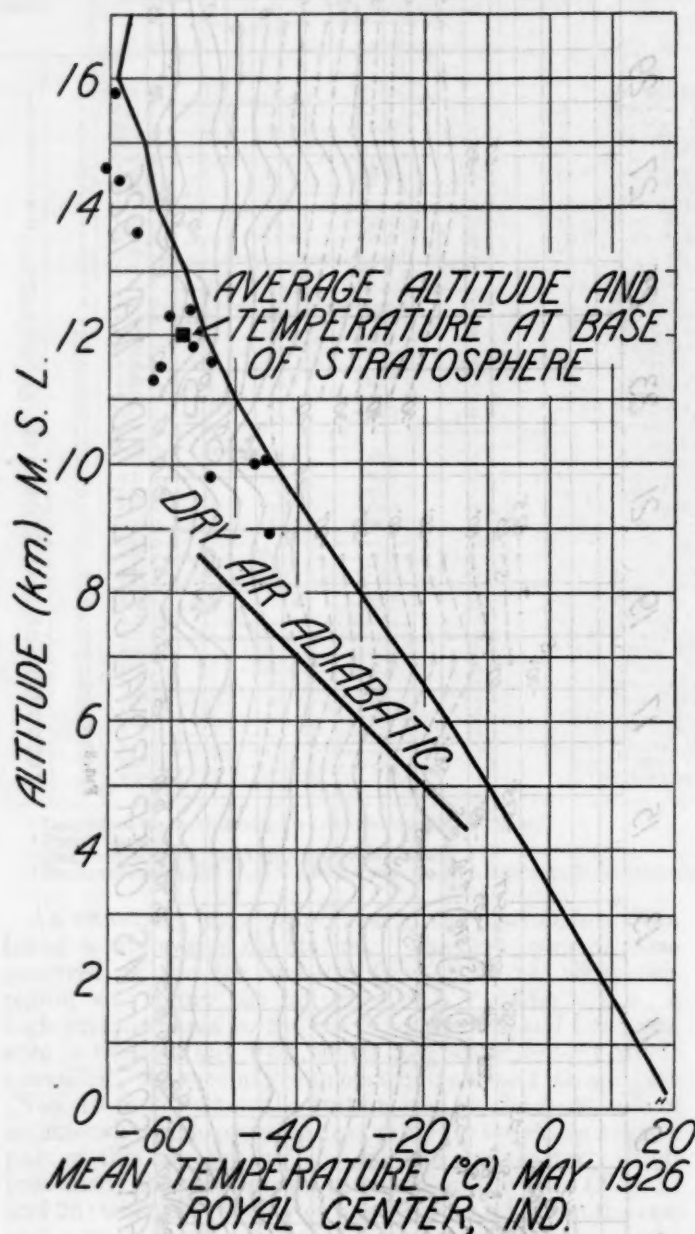


FIG. 4

the drop in temperature due to radiation was confined to the air below 2,000 m. (M. S. L.).

The fall in temperature on the other dates mentioned, viz, the 3d, 19th, 22d, and 26th occurred in connection with the passage of a high pressure area. It is interesting to note the height to which the temperature fell in each of these cases. It will also be observed that this lower stratum, wherein the temperature decreased, was

surmounted in each case either by an inversion or by an isothermal layer.

Separated from these more or less marked fluctuations found in the lower levels by a layer several kilometers thick wherein the temperature changes were relatively small there occurred in the higher levels a series of rather pronounced fluctuations in temperature. (See fig. 3.) The latter appear to be definitely associated with the altitude of the base of the stratosphere. Thus when the temperature rises at these levels the stratosphere also rises, whereas when the temperature falls the base of the stratosphere is found to have lowered. This relationship is apparently confined to the temperature changes at these higher elevations. W. H. Dines has found the correlation coefficient between the temperature at 8 kms. and the altitude of the stratosphere to be 0.74 with a small probable error. (2)

Figure 4 shows the mean temperature for the month, based on 28 observations, only one being used on days when more were made. The dots indicate the altitude and temperature of the base of the stratosphere for the individual observations, the extreme range (6.9 kms.) being nearly equal to the minimum altitude (8.9 kms.) above sea-level. The mean altitude of the base of the stratosphere was 12.0 kms. and the mean temperature -58.4°C . The range in temperature at the base of the stratosphere was 26.4°C , i. e., from -44.5°C . to -70.9°C . Note that all of the points fall to the left of the mean curve, i. e., the temperature at the base of the stratosphere at any particular time is always lower than the mean temperature for that altitude. This is also brought out when the mean temperature for the base of the stratosphere, based on the 14 observations which reached it, is compared to the mean for the same altitude as shown by the curve. (See temperature indicated by square and that indicated by curve at 12 kms., fig. 4.) The reason for this is that in the individual observations the temperature usually increases abruptly at the base of the stratosphere and also because the stratosphere fluctuates in height thus causing the mean curve to fall to the right.

The relation between the altitude of the base of the stratosphere and the corresponding temperature is clearly shown by the distribution of the dots on this chart. Thus, when the stratosphere is low, its temperature is in general higher than when the stratosphere is high. The correlation coefficient found by Dines for these two variables is -0.68 with a small probable error. Some of the more significant other correlation coefficients obtained by Dines are given in Table 5. (2)

TABLE 5.—Correlation coefficients

	P_0	P_1	T_{1-9}	H_s	T_s	T_8
P_0.....		.68	.47	.68	-.52	
P_1.....	.68		.95	.84	-.47	
T_{1-9}.....	.47	.95		.79	-.37	
H_s.....	.68	.84	.79		-.68	.74
T_s	-.52	-.47	-.37	-.68		
T_8.....				.74		

P_0 is the barometric pressure at M. S. L.

P_1 is the barometric pressure at 9 km.

T_{1-9} is the mean temperature from 1 to 9 km.

H_s is the height of the base of the stratosphere.

T_s is the temperature at the base of the stratosphere.

T_8 is the temperature at 8 km.

TABLE 6.—Mean temperatures (°C)

Altitude (km.) M. S. L.	Equatorial (annual)	St. Louis ¹ (May, 1906) Lat. 38° 38' N.	Royal Center (May, 1926) Lat. 40° 53' N.	Toronto ² (annual) Lat. 43° 40' N.	London ³ (annual) Lat. 51° 30' N.	Pavlovsk ⁴ (annual) Lat. 59° 41' N.
1.	22.0	8.1	13.9	5.3	5.0	-1.8
2.	17.0	1.6	8.2	1.8	0.2	-6.4
3.	12.0	-4.1	2.2	-3.4	-5.3	-12.0
4.	6.0	-10.1	-3.7	-8.9	-11.3	-17.8
5.	-1.0	-15.9	-10.1	-15.3	-18.2	-23.9
6.	-8.0	-21.1	-16.3	-22.1	-25.2	-30.3
7.	-15.0	-28.2	-23.2	-29.5	-32.3	-37.1
8.	-22.0	-36.4	-30.3	-37.1	-39.4	-43.3
9.	-30.0	-44.5	-37.3	-43.7	-45.5	-48.0
10.	-38.0	-52.0	-44.1	-49.8	-50.8	-50.4
11.	-46.0	-55.8	-50.1	-53.7	-53.4	-51.3
12.	-54.0	-57.4	-55.0	-56.8	-54.2	-51.0
13.	-62.0	-57.7	-58.1	-59.0	-54.3	
14.	-70.0	-58.5	-62.7	-60.5	-54.1	
15.	-75.0	-60.4	-64.7	-62.0		
16.	-78.0	-59.2	-66.0	-62.1		
17.	-80.0		-66.9	-61.6		

MEAN TEMPERATURE GRADIENTS

1.	5.0	6.5	5.7	3.5	4.8	4.6
2.	5.0	5.7	6.0	5.2	5.5	5.6
3.	6.0	6.0	5.9	5.5	6.0	5.8
4.	7.0	5.8	6.4	6.4	6.9	6.1
5.	7.0	5.2	6.2	6.8	7.0	6.4
6.	7.0	7.1	6.9	7.4	7.1	6.8
7.	7.0	8.2	7.1	7.6	7.1	6.2
8.	8.0	8.1	7.0	6.6	6.1	4.7
9.	8.0	7.5	6.8	6.1	5.3	2.4
10.	8.0	3.8	6.0	3.9	2.6	0.9
11.	8.0	1.6	4.9	3.1	0.8	-0.3
12.	8.0	0.3	3.1	2.2	0.1	
13.	8.0	0.8	4.6	1.5	-0.2	
14.	5.0	1.9	2.0	1.5		
15.	3.0	-1.2	4.3	0.1		
16.	2.0		-2.1	-0.5		
17.						
Number of observations		18	28	53	167	90

¹ Monthly Weather Review November, 1915.² Annals Harvard College Observatory Vol. 68, Part 1, 1909.³ Upper Air Investigation in Canada, Part 1, 1915.⁴ Geophysical Memoirs No. 13, 1919.⁵ Meteorologische Zeitschrift, January, 1911.

Table 6 contains the mean temperatures and temperature gradients at several stations in latitudes ranging from the equator to practically 60° N. The values represent annual means for all of the stations except Royal Center and St. Louis which are for May. However, since there is usually little difference between spring and annual means practically the same agreement may be expected as if all were annual values. The average maximum gradient is indicated in bold-face type; it occurs at practically the same elevation at all of the stations. The maximum gradient is found at that altitude above which about one-third of the atmosphere exists. The equatorial observations show a persistence in the maximum gradient for a much greater interval than occurs at the other stations.

Figure 5 is a graphical representation of Table 6 and brings out a number of striking features. Among these is the opposite relationship as regards the latitudinal variation which occurs between the temperatures in the stratosphere and those in the troposphere. Although contrary to expectations in this respect, the temperatures in the stratosphere are higher at St. Louis than at Royal Center and Toronto. This is probably due to the relatively small difference in latitude between these places as well as to a possibly insufficient number of observations, especially in the higher levels, to determine true averages.

The inverse relationship existing between the average height of the stratosphere and the latitude is especially well shown in this figure, the wide difference between this altitude at the Russian station as compared to that over the equator being particularly striking.

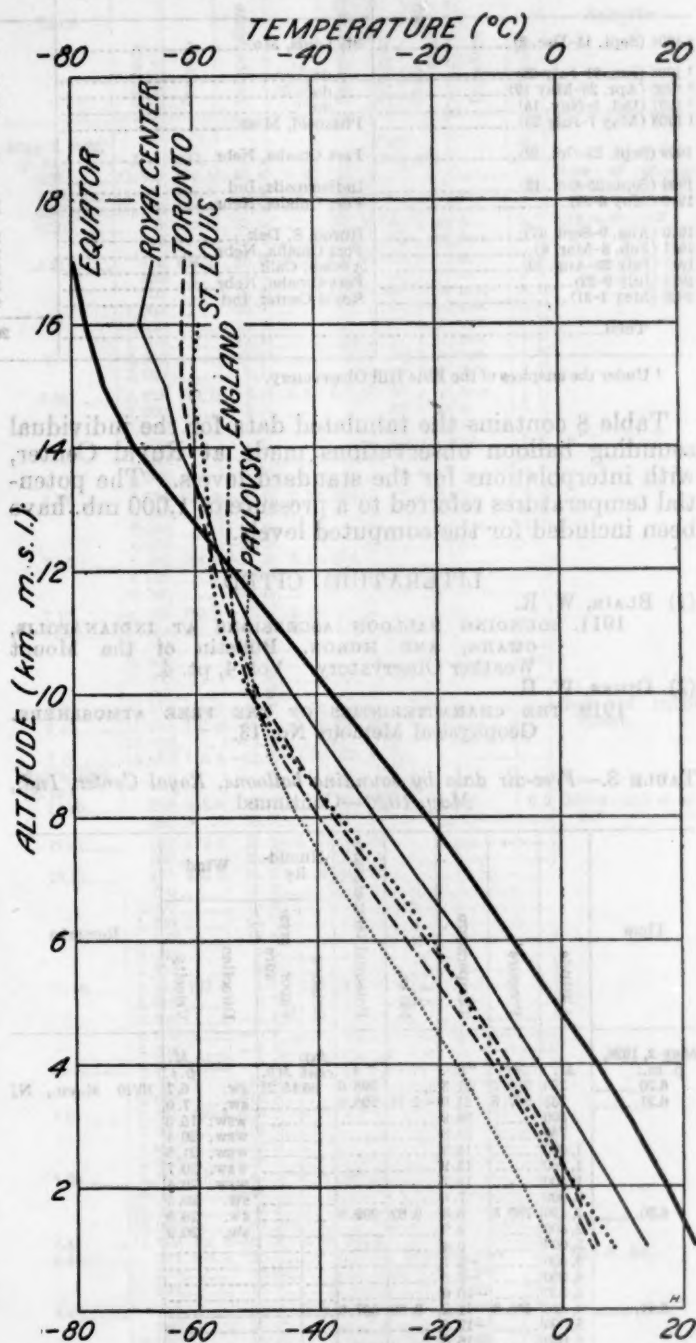


FIG. 5.—Mean vertical temperature distribution for stations in widely different latitudes. (See Table 6.)

Another feature brought out is the convergence of the lines at about 12 km., indicating practically the same mean temperature at this elevation at all of these widely separated places.

Table 7 contains a condensed summary of all previous sounding balloon observations made in this country.

TABLE 7.—Series of sounding balloon observations made in United States to and including 1926

Date	Place of observation	Number of ascensions	Number of instruments returned	Number of good records	Number that entered stratosphere	Maximum altitude (m.) M. S. L.	Where published
1904 (Sept. 15-Dec. 2)	St. Louis, Mo.	14	14	13	3	17,045	Annals Harvard College Observatory, vol. 68, pt. 1.
1905 (Jan. 21-July 25)	do	21	18	13	5	16,790	Do.
1906 (Apr. 23-May 19)	do	21	21	20	11	16,457	Do.
1907 (Oct. 5-Nov. 15)	do	21	10	18	10	16,640	Do.
1908 (May 7-July 28)	Pittsfield, Mass.	4	3	3	1	17,695	Annals Harvard College Observatory, vol. 68, pt. 2.
1909 (Sept. 25-Oct. 12)	Fort Omaha, Nebr.	13	12	12	6	24,119	Bulletin Mount Weather Observatory, 1910, vol. 3, pt. 3.
1909 (Sept. 25-Oct. 12)	Indianapolis, Ind.	7	6	5	4	19,443	Do.
1910 (May 6-22)	Fort Omaha, Nebr.	20	16	16	1	25,303	Bulletin Mount Weather Observatory, 1911, vol. 4, pt. 4.
1910 (Aug. 9-Sept. 17)	Huron, S. Dak.	26	24	23	19	30,486	Do.
1911 (Feb. 8-Mar. 4)	Fort Omaha, Nebr.	25	22	22	21	24,105	Do.
1913 (July 23-Aug. 10)	Avalon, Calif.	23	15	13	10	32,643	Monthly Weather Review, July, 1914.
1914 (July 9-22)	Fort Omaha, Nebr.	21	20	19	15	31,602	Monthly Weather Review, May, 1916.
1926 (May 1-31)	Royal Center, Ind.	44	39	36	14	17,182	
Total		290	229	213	120		

¹ Under the auspices of the Blue Hill Observatory.

Table 8 contains the tabulated data for the individual sounding balloon observations made at Royal Center, with interpolations for the standard levels. The potential temperatures referred to a pressure of 1,000 mb. have been included for the computed levels.

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1911. SOUNDING BALLOON ASCENSIONS AT INDIANAPOLIS, OMAHA, AND HURON. Bulletin of the Mount Weather Observatory. Vol. 4, pt. 4.
- (2) DINES, W. H.
1919. THE CHARACTERISTICS OF THE FREE ATMOSPHERE. Geophysical Memoirs No. 13.

TABLE 8.—Free-air data by sounding balloons, Royal Center, Ind., May, 1926—Continued

Time	Altitude	Pressure	Temperature	Δt 100 m.	Potential temperature	Humidity		Wind		Remarks
						Relative	Vapor pressure	Direction	Velocity	
May 2, 1926, p. m.:	M.	Mb.	° C.		° A.	Per cent	Mb.		M.	
6.20	225	980.7	21.3		296.0	60	15.21	sw.	6.7	10/10 st.-cu., N ₂
6.21	253	977.6	21.9	-2.14	296.8			sw.	7.0	
	500		19.9					ws.	16.0	
	750		17.8					ws.	20.4	
	1,000		15.8					ws.	21.6	
	1,250		13.9					ws.	20.7	
	1,500		11.7					ws.	20.4	
	2,000		7.6					sw.	20.5	
6.30	2,156	780.5	6.3	0.82	299.8			sw.	20.5	
	2,500		3.9					sw.	20.9	
	3,000		0.4							
	3,500		-3.1							
	4,000		-6.5							
	4,500		-10.0							
6.41	4,676	568.8	-11.2	0.69	307.6					
	5,000		-12.6							
	6,000		-16.8							
6.48	6,590	442.0	-19.3	0.42	320.4					
	7,000		-22.4							
6.53	7,704	380.2	-27.6	0.75	323.6					
May 3, 1926, p. m.:										
6.18	225	997.3	9.3		282.5	66	7.73	n.	7.2	2/10 cl.-st., WNW
	250		8.9			66	7.52	n.	7.2	
	500		4.6			70	5.94	nnw.	8.1	
	750		0.3			75	4.68	n.	9.0	
6.22	963	910.5	-3.3	1.71	277.0	78	3.63	n.	10.7	
	1,000		-2.9			77	3.70	n.	11.0	
	1,250		-0.2			69	4.15	n.	10.5	
6.24	1,274	875.4	0.1	-1.09	283.7	68	4.18	n.	10.4	
	1,500		-0.5			66	3.87	n.	12.0	
	2,000		-1.8			62	3.27	nnw.	17.2	
	2,500		-3.1			59	2.79	nnw.	15.3	
	3,000		-4.5			55	2.32	nnw.	15.4	
	3,500		-5.8			51	1.92	nw.	19.4	
6.32	3,610	651.9	-6.1	0.27	301.6	50	1.84	nw.	19.8	

TABLE 8.—Free-air data by sounding balloons, Royal Center, Ind., May, 1926—Continued

Time	Altitude	Pressure	Temperature	Δt 100 m.	Potential temperature	Humidity		Wind		Remarks
						Relative	Vapor pressure	Direction	Velocity	
May 3, 1926, p. m.:	M.	Mb.	° C.		° A.	Per cent	Mb.		M.	
6.35	3,995	621.0	-5.5	-0.16	306.5	50	1.94	nw.	20.0	
	4,500		-9.8			49	1.31	nw.	19.6	
	5,000		-14.1			48	0.87	nw.	21.8	
6.41	5,272	525.9	-16.4	0.85	308.3	48	0.71	nw.	21.2	
May 4, 1926, p. m.:										
6.11	225	994.2	15.0		288.5	49	8.36	se.	4.0	8/10 cl.-st., NNW
	250		14.8			49	8.25	se.	4.2	
	500		12.7			49	7.20	se.	6.3	
	750		10.6			48	6.13	s.	8.5	
6.15	891	918.1	9.4	0.84	289.4	48	5.06	s.	8.6	
	1,000		9.3			46	5.39	s.	7.8	
	1,250		9.1			42	4.86	s.	5.0	
6.16	1,384	885.2	9.0	0.08	293.9	40	4.59	ssw.	2.3	
	1,500		8.5			42	4.66	sw.	1.8	
6.19	1,962	806.9	6.3	0.47	297.0	50	4.77	nw.	5.5	
	2,000		6.1			50	4.70	nw.	6.0	
	2,500		3.9			51	4.12	wnw.	13.7	
6.24	2,980	712.0	1.8	0.44	302.8	52	3.61	wnw.	16.4	
	3,000		1.7			52	3.59	wnw.	16.6	
	3,500		-2.1			58	2.98	wnw.	18.8	
6.29	3,988	629.5	-5.5	0.75	305.4	63	2.44	nw.	21.2	
	4,000		-5.9			64	2.39	nw.	21.2	
	4,500		-10.5			72	1.81	nw.	18.1	
	5,000		-15.1			81	1.34			
6.39	5,538	512.5	-20.0	0.92	306.3	90	0.94			
	6,000		-22.0			88	0.76			
	7,000		-26.2			84	0.48			
	8,000		-30.5			79	0.28			
6.46	8,243	354.0	-31.5	0.42	325.0	78	0.26			
May 5, 1926, p. m.:										
6.06	225	999.5	20.6		294.5	25	6.07	sw.	2.7	Few cl.? (too
	250		21.2					sw.	3.2	low on horizon
6.07	368	973.3	24.2	-2.52	299.5			sw.	5.6	to observe with
	500		23.4					sw.	8.2	nephoscope).
6.09	641	943.3	22.5	0.62	300.5			sw.	9.0	
	750		21.5					ssw.	9.3	
	1,000		19.1					ssw.	8.0	
	1,250		16.7					ssw.	8.0	
6.13	1,441	859.4	14.9	0.95	300.6			ssw.	9.2	
	1,800		14.5					ssw.	9.5	
	2,000		10.9					ws.	11.4	
6.17	2,145	790.0	9.9	0.71	302.6			ws.	13.0	
	2,500		7.4					ws.	14.0	
6.22	2,806	728.8	5.3	0.69	304.6			wnw.	12.7	
	3,000		5.3					wnw.	10.1	
6.24	3,096	703.5	5.3	0.00	307.7			wnw.	9.0	
	3,500		2.7					nw.	6.0	
6.26	3,512	668.3	2.6	0.65	309.3			nw.	6.0	
	4,000		-1.6					nnw.	3.1	
	4,500		-5.8					nnw.	2.2	
6.32	4,531	588.5	-6.1	0.86	310.6			nnw.	2.3	
6.34	4,773	570.4	-7.1	0.41	312.2			nnw.	4.5	
6.34½	4,853	564.9	-6.5	-0.75	313.8			wnw.	6.5	
	5,000		-7.3					w.	8.6	
6.36	5,146	544.0	-8.0	0.51	315.4			w.	7.6	
6.38	5,446	523.5	-8.0	0.00	318.9			wnw.	7.6	

TABLE 8.—Free-air data by sounding balloons, Royal Center, Ind., May, 1926—Continued

Time	Altitude	Pressure	Temperature	Δt 100 m.	Potential temperature	Humidity		Wind		Remarks
						Relative	Vapor pressure	Direction	Velocity	
May 5, 1926, p. m.:	M.	Mb.	°C.		°A.	Per cent	Mb.		M.	
6.38	6,000		-12.0					nw.	8.4	
	7,000		-19.3					nw.	8.1	
6.50	8,000		-26.6							
	8,211	362.3	-28.1	0.73	327.4					
	9,000		-35.9							
	10,000		-45.7							
7.02	10,138	275.5	-47.0	0.98	326.8					
	11,000		-55.2							
7.12	11,997	205.5	-64.6	0.95	327.7					
May 6, 1926, p. m.:										
6.09	225	988.2	23.3		297.3	32	9.16	se.	3.1	4/10 cl. and cl.-st., wnw.
	250		23.5			31		se.	3.6	
6.10	468	961.2	25.4	-0.86	301.8	25	8.12	se.	6.4	
	500		25.2			25		se.	6.2	
	750		23.3			25		se.	7.7	
	1,000		21.4			25		se.	7.0	
	1,250		19.5			24		se.	5.3	
	1,500		17.6			24		se.	5.4	
6.17	1,627	840.4	16.7	0.75	304.5	24	4.56	se.	4.8	
	2,000		13.4			25		se.	2.4	
	2,500		9.0			27		e.	1.6	
6.24	2,799	730.3	6.3	0.89	305.6	28	2.67	e.	3.0	
	3,000		7.0			28		e.	5.6	
6.26	3,071	706.9	7.2	-0.33	309.4	28	2.84	e.	6.1	
	3,500		4.4			27		ese.	5.9	
6.30	3,795	646.6	2.5	0.65	312.1	27	1.97	se.	7.2	
	4,000		0.9			27		se.	8.0	
	4,500		-3.1			26		sse.	10.8	
6.36	4,705	577.2	-4.7	0.79	314.0	26	1.08	sse.	11.4	
	5,000		-5.1			25		sse.	10.4	
6.40	5,485	523.0	-5.8	0.14	321.6	24	0.90	se.	10.2	
	6,000		-10.1			23		se.	9.0	
6.44	6,278	472.5	-12.4	0.83	322.9	22	0.47	se.	8.6	
6.47	6,739	444.6	-14.9	0.54	325.4	22	0.37	se.	8.6	
	7,000		-17.5			22		se.	8.6	
	8,000		-27.3			22		s.	7.2	
6.56	8,042	373.3	-27.7	0.98	328.2	22	0.11	s.	7.4	
	9,000		-33.2					e.	2.1	
	10,000		-38.8					e.	4.0	
7.06	10,643	258.9	-42.5	0.57	339.2			se.	3.2	
	11,000		-44.2							
	12,000		-49.1							
	13,000		-53.9							
7.19	13,363	172.7	-55.7	0.49	359.1					
	14,000		-59.2							
	15,000		-64.7							
7.28	15,840	116.7	-69.3	0.55	376.5					Base of strato- sphere.
	16,000		-69.0							
	17,000		-66.9							
7.33	17,182	94.2	-66.5	-0.21	405.8					
May 7, 1926, a. m.:										
7.06	225	990.5	22.1		295.9	70	18.63	se.	4.5	5/10 cl. and cl.-st., WSW.
	250		22.2					se.	4.8	
	500		23.3					e.	7.7	
7.08	565	952.6	23.6	-0.44	300.7			e.	8.2	
	750		22.2					e.	8.4	
	1,000		20.4					e.	7.8	
	1,250		18.5					e.	8.7	
	1,500		16.7					ene.	7.9	
7.14	1,702	834.8	15.2	0.74	303.5			ene.	6.9	
May 7, 1926, p. m.:										
1.09	225	988.2	29.6		303.6	31	12.57	se.	3.1	5/10 cl. and cl.-st., WSW.
	250		29.3					se.	3.2	
	500		26.5					se.	4.2	
	750		23.6					se.	4.4	
1.10	892	916.1	22.0	1.14	302.5			se.	4.5	
	1,000		21.0					se.	4.5	
	1,250		18.6					se.	4.6	
	1,500		16.2					se.	4.6	
	2,000		11.3					sse.	5.4	
1.14	2,056	790.1	10.8	0.90	302.6			sse.	5.3	
1.16	2,372	769.2	8.4	0.76	303.3			sse.	5.4	
	2,500		8.3					sse.	6.0	
1.18	2,692	740.0	8.2	0.66	306.5			s.	6.1	
	3,000		5.8					sse.	7.5	
	3,500		2.0					s.	7.0	
	4,000		-1.9					s.	7.0	
	4,500		-5.7							
1.34	4,627	682.2	-6.7	0.77	310.9					
	5,000		-7.3							
1.38	5,296	634.4	-7.8	0.16	317.2					
	6,000		-13.2							
	7,000		-21.0							
	8,000		-28.7							
1.53	8,179	364.4	-30.1	0.77	324.2					
	9,000		-35.1							
2.03	9,092	320.7	-35.6	0.60	328.7					
	10,000		-42.2							
	11,000		-49.5							
2.15	11,227	234.9	-51.1	0.73	335.8					
	12,000		-57.8							

TABLE 8.—Free-air data by sounding balloons, Royal Center, Ind., May, 1926—Continued

Time	Altitude	Pressure	Temperature	Δt 100 m.	Potential temperature	Humidity		Wind		Remarks
						Relative	Vapor pressure	Direction	Velocity	
May 7, 1926, p. m.:	M.	Mb.	°C.		°A.	Per cent	Mb.		M.	
2.23	12,300	199.5	-60.4	0.87	337.1					Base of strato- sphere.
2.25	12,761	186.3	-56.9	-0.78	349.4					
2.25½	12,798	184.8	-57.8	1.92	348.8					
6.20	225	985.4	22.0		296.2	35	9.26	e.	2.7	6/10 cl.-st., SW.
	250		22.4			34	9.22	e.	2.7	
6.21	410	964.7	25.3	-1.78	301.4	25	8.07	e.	2.8	
	500		24.5			25	7.69	e.	2.9	
	750		22.3			26	7.00	ese.	3.3	
	1,000		20.2			26	6.16	ese.	3.3	
	1,250		18.0			27	5.58	ese.	3.8	
	1,500		15.8			27	4.85	ese.	4.7	
	2,000		11.5			29	3.94	ese.	5.6	
	2,500		7.1			30	3.03	ssw.	3.3	
6.36	2,628	742.5	6.0	0.87	303.8	30	2.80	ssw.	3.1	
	3,000		3.7			30	2.39	s.	3.0	
	3,500		0.6			29	1.85	s.	5.2	
	4,000		-2.6			29	1.43	se.	9.5	
	4,500		-5.7			29	1.10	s.	10.5	
	5,000		-8.8			28	0.81	s.	9.2	
6.51	5,336	628.4	-10.9	0.62	314.6	28	0.68	s.	9.8	
	6,000		-14.7					se.	10.3	
	7,000		-20.5					se.	3.7	
	8,000		-26.3							
7.11	8,878	328.6	-31.4	0.58	332.1					
	9,000		-32.2							
	10,000		-38.6							
7.17	10,029	279.3	-38.8	0.64	337.3					
7.21	10,863	247.4	-42.2	0.41	344.1					
	11,000		-43.2							
	12,000		-50.6							
	13,000		-57.9							
	14,000		-65.3							
7.39	14,444	143.2	-68.6	0.74	356.4					Base of strato- sphere.
7.41	14,932	132.6	-64.1	-0.92	372.3					
	15,000		-63.8							
7.47	15,600	119.4	-61.5	-0.39	388.4					
May 8, 1926, a. m.:										
12.30	225	985.8	15.0		289.2	70	11.94	n.	0.9	3/10 cl. and cl.-st., S?
	250		16.0							
12.31	358	970.6	20.2	-3.91	295.7					
	500		20.6							
12.33	671	936.0	21.0	-0.26	299.6					
	750		20.3							
	1,000		18.0							
	1,250		15.7							
	1,500		13.5							
	2,000		9.0							
	2,500		4.4							
12.46	2,821	723.4	1.5	0.91	301.1					
	3,000		0.3							
	3,500		-3.1							
	4,000		-6.4							
	4,500		-9.8							
12.57	4,517	583.8	-9.9	0.67	306.9					
	5,000		-12.6							
	6,000		-18.3							
1.08	6,334	459.8	-20.2	0.57	315.7					
	7,000		-24.9							
	8,000		-32.0							
	9,000		-39.1							
1.25	9,248	307.0	-40.9	0.71	325.4					
	10,000		-46.2							
	11,000		-53.2							
	12,000		-60.2							
1.45	12,719	181.3	-65.2	0.73	338.6					
6.45	225	984.8	15.8		290.16	90	16.16	ene.	2.7	2/10 cl. SE.
	250		16.0					ene.	2.4	
	500		13.4					se.	1.5	
6.48	1,723	885.5	20.6	-						

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TABLE 8.—Free-air data by sounding balloons, Royal Center, Ind., May, 1926—Continued

Time	Altitude	Pressure	Temperature	$\frac{\Delta t}{100 \text{ m.}}$	Potential temperature	Humidity		Wind		Remarks
						Relative	Vapor pressure	Direction	Velocity	
May 8, 1926, a. m.:	M.	Mb.	° C.		° A.	Per cent	Mb.		M.	
7.55	11,775		-54.1	0.76				se.	p. s.	
	12,000		-55.1					sse.	3.1	
7.59	12,406		-57.0	0.46				sse.	3.7	
8.02	12,845		-57.9	0.20				sw.	4.9	Base of strato- sphere.
	13,000		-58.7					sw.	5.6	
8.03	13,050		-58.9	0.40				ws.	7.0	
May 8, 1926, p. m.:								w.	7.2	
6.20	225	981.0	20.9		295.5	70	17.31	ne.	1.8	6/10 A.-st., a.-cu.,
	250		21.3					ne.	2.2	SSW., and 4/10
6.21	422	959.0	24.0	-1.57	300.6			ne.	4.8	st.-nb., SW.
	500		23.4					ne.	6.0	
	750		21.5					ne.	4.5	
	1,000		19.7					ne.	3.9	
	1,250		17.8					n.	3.4	
	1,500		15.9					n.	4.3	
6.26	1,754	821.4	14.0	0.75	303.6			nw.	6.7	
	2,000		11.7					wnw.	9.0	
	2,500		7.1					w.	9.6	
6.30	2,823	722.0	4.2	0.92	304.3			ws.	9.6	
	3,000		2.9					sw.	9.4	
	3,500		-0.9					sw.	9.3	
	4,000		-4.7					sw.	9.2	
6.39	4,373	594.7	-7.5	0.75	308.0			ssw.	10.4	
	4,500		-8.1					s.	10.8	
6.42	4,796	563.3	-9.5	0.47	310.5			s.	9.0	
	5,000		-11.2							
	6,000		-19.6							
	7,000		-28.1							
6.53	7,352	400.5	-31.0	0.84	313.6					
	8,000		-38.7							
6.58	8,021	364.2	-38.9	1.18	312.5					
7.01	8,499	340.2	-41.8	0.61	314.7					
	9,000		-45.7							
7.05	9,288	303.2	-47.9	0.77	316.7					
May 9, 1926, p. m.:										
6.21	225	977.0	16.8		291.7	80	15.31	w.	4.5	10/10 A.-st., NW.
	250		16.7					w.	4.4	
	500		15.2					wnw.	3.8	
	750		13.8					w.	1.7	
	1,000		12.4					ws.	1.5	
	1,250		11.0					sw.	3.6	
	1,500		9.6					sw.	4.7	
6.28	2,000		6.7					sw.	4.9	
	2,063	784.3	6.4	0.57	299.5			sw.	4.4	
	2,500		4.3					sw.	1.8	
6.30	2,651	730.0	3.6	0.48	302.6					
	3,000		0.8							
	3,500		-3.2							
6.35	3,728	638.0	-5.0	0.80	304.8					
	4,000		-6.1							
6.37	4,070	610.9	-6.4	0.41	307.0					
	4,500		-8.9							
	5,000		-11.8							
	6,000		-17.6							
6.48	6,589	439.3	-21.0	0.58	318.8					
	7,000		-23.8							
	8,000		-30.6							
	9,000		-37.4							
7.00	9,079	311.7	-37.9	0.68	328.1					
	10,000		-43.5							
	11,000		-49.5							
7.09	11,114	231.1	-50.2	0.61	338.7					
7.11	11,557	216.6	-53.5	0.75	340.0					Base of strato- sphere.
	12,000		-53.4							
	13,000		-53.2							
7.17	13,747	185.1	-53.0	-0.62	374.9					
May 10, 1926, a. m.:										
7.03	225	976.6	11.7		286.6	60	8.25	e.	5.4	10/10 st., SSE.
	250		11.3					e.	6.0	
7.04	430	952.8	8.3	1.66	285.2			sse.	9.0	
	500		8.8					sse.	9.7	
7.05	715	920.6	10.3	-0.70	290.1			se.	10.0	
	750		10.0					se.	9.4	
7.06	982	891.6	8.3	0.72	290.7			sse.	5.4	
	1,000		8.4					s.	5.0	
7.06½	1,047	884.5	8.7	-0.62	291.3					
	1,250		7.7							
	1,500		6.5							
	2,000		4.1							
	2,500		1.7							
7.14	2,683	722.6	0.8	0.48	300.5					
	3,000		-0.2							
	3,500		-1.8							
	4,000		-3.4							
	4,500		-5.0							
	5,000		-6.6							
7.26	5,268	522.2	-7.5	0.32	319.7					
	6,000		-10.2							
7.36	6,790	428.6	-13.1	0.37	331.2					

TABLE 8.—Free-air data by sounding balloons, Royal Center, Ind.,
May, 1926—Continued

Time	Altitude		Pressure	Temperature		$\frac{\Delta t}{100 \text{ m.}}$	Potential temperature	Humidity		Wind		Remarks
	M.	Mb.		° C.	° F.			Per cent	Mb.	Direction	Velocity	
May 11, 1926,												
a. m.:												
6.25	225	988.2		6.7			280.7	85	8.34	ne.		Cloudless.
	250			6.4						ne.	4.5	
6.26	403	967.0		4.9	1.01		280.6			ne.	5.0	
6.26½	501	955.4		5.7	-0.82		282.4			ne.	8.0	
	750			4.7						e.	8.4	
6.29	927	907.0		4.0	0.40		284.8			ene.	8.6	
	1,000			4.7						ne.	10.8	
6.30	1,000	892.2		5.3	-0.96		287.5			ne.	10.8	
	1,250			4.7						ne.	11.0	
	1,500			4.0						ne.	12.0	
6.34	1,749	819.9		3.3	0.29		292.4			ene.	9.2	
	2,000			1.4						ne.	11.0	
6.37	2,183	776.9		0.1	0.74		293.5			ne.	11.2	
6.39	2,416	754.9		2.8	-1.16		298.9			ne.	14.2	
	2,500			2.3						ne.	11.4	
	3,000			-0.5						ne.	10.6	
	3,500			-3.3						n.	10.1	
	4,000			-6.1						n.	8.2	
6.48	4,069	613.7		-6.5	0.56		306.4			n.	8.4	
6.49	4,204	602.8		-5.8	-0.51		308.8			n.	9.2	
	4,500			-7.4						ene.	12.2	
	5,000			-10.1						ne.	12.8	
	6,000			-15.6						ne.	9.0	
7.00	6,753	432.1		-19.6	0.54		322.1			ne.	13.6	
	7,000			-21.1						ne.	13.6	
	8,000			-27.3						ne.	10.4	
7.11	8,857	324.1		-32.3	0.60		332.2			ne.	14.6	
	9,000			-33.1						ene.	11.8	
	10,000			-38.9						ne.	11.8	
	11,000			-44.7						ese.	6.0	
	12,000			-50.5						w.	15.6	
7.37	12,146	200.9		-51.3	0.58		350.8			w.	17.0	
7.30	12,526	189.6		-52.8	0.39		355.5			w.	18.0	
May 11, 1926,												
p. m.:												
5.43	225	980.8		16.0			290.1	45	8.19	n.	8.9	Few cl., F.
	250			15.6						n.	9.0	
	500			12.1						n.	9.4	
5.46	621	941.3		10.4	1.42		288.3			n.	8.4	
5.47	701	932.4		10.8	-0.50		289.5			n.	7.4	
	750			10.4						n.	6.8	
	1,000			8.6						ene.	5.8	
	1,250			6.8						ne.	6.7	
	1,500			5.0						ene.	7.9	
	2,000			1.3						e.	7.9	
5.54	2,096	786.2		0.6	0.73		293.1			e.	8.3	
5.55	2,218	774.5		0.9	0.25		294.7			e.	11.8	
	2,500			0.8						ene.	14.0	
5.57	2,587	739.8		0.8	0.03		298.4			ene.	13.9	
5.58	2,722	727.4		1.1	-0.22		300.2			ene.	12.7	
	3,000			-0.3						ene.	15.0	
	3,500			-2.8						ene.	11.6	
	4,000			-5.3						ene.	10.7	
6.07	4,139	608.8		-6.0	0.50		307.7			ene.	10.2	
	4,500			-8.3						ene.	7.4	
6.10	4,733	562.4		-9.9	0.64		310.2			ene.	7.2	
	5,000			-11.9						e.	6.4	
6.12	5,211	530.1		-13.7	0.83		310.9			e.	11.6	
	6,000			-20.6						e.	15.2	
	7,000			-29.3						e.	17.7	
6.25	7,352	396.6		-32.4	0.87		313.5			e.	12.2	
	8,000			-37.4						e.	10.5	
	9,000			-45.2						se.	4.4	
6.37	9,749	280.3		-51.0	0.78		319.4			c.	4.7	
	10,000			-52.5						e.	7.0	
	11,000			-58.5						sw.	2.0	Base of strato-
6.46	11,543	212.8		-61.8	0.60		328.0			sw.	5.6	sphere.
	12,000			-61.2						sw.	6.6	
6.50	12,136	193.6		-61.0	-0.13		339.1			w.	8.1	
6.51	12,373	186.8		-59.1	-0.80		345.6			ws	9.5	
6.53	12,611	179.8		-58.7	-0.17		350.1			w.	5.4	
6.54	12,901	172.1		-57.1	-0.55		357.1			w.	5.0	
	13,000			-56.3						w.	5.6	
6.56	13,085	167.5		-55.6	-0.82		362.4			w.	5.6	
May 12, 1926,												
a. m.:												
6.35	225	988.5		13.4			287.3	70	10.77	ese.	3.1	Few cl., ESE.
	250			13.2						ese.	3.3	
	500			11.5						ese.	6.0	
	750			9.8						ese.	5.8	
6.41	1,000			8.1						ne.	5.5	
	1,209	877.7		6.7	0.68		290.3			n.	5.0	
	1,250			6.4						n.	5.5	
	1,500			4.8						n.	7.5	
6.44	1,811	815.3		2.8	0.65		292.4			n.	6.3	
	2,000			2.3						n.	4.9	
6.49	2,498	748.7		0.9	0.28		297.5			n.	4.6	
6.50	2,726	727.9		1.5	-0.26		300.6			n.	3.7	
	3,000			0.0						n.	3.5	
	3,500			-2.8						n.	5.6	
6.57	3,969	622.8		-5.4	0.56		306.4			ene.	6.2	
	4,000			-5.6						ene.	6.2	

TABLE 8.—Free-air data by sounding balloons, Royal Center, Ind., May, 1926—Continued

Time	Altitude	Pressure	Temperature	$\frac{\Delta t}{100 \text{ m.}}$	Potential temperature	Humidity		Wind		Remarks
						Relative	Vapor pressure	Direction	Velocity	
May 14, 1926, a. m.:										
6.47	3,537	652.8	-7.1	0.61	299.5					
	4,000		-9.6							
	4,500		-12.4							
	5,000		-15.1							
	6,000		-20.6							
7.03	6,735	428.2	-24.6	0.55	316.6					
	7,000		-26.0							
	8,000		-31.5							
7.12	8,203	340.3	-32.6	0.55	324.9					
	9,000		-37.9							
	10,000		-44.4							
7.21	10,068	267.5	-44.9	0.66	332.6					Base of stratosphere.
7.23	10,705	243.4	-46.0	0.17	340.0					
	11,000		-46.8							
7.26	11,408	219.6	-47.8	0.26	347.4					
May 14, 1926, p. m.:										
5.30	225	985.1	15.1		280.3	75	12.88	w.	7.2	10/10 st., NW.
	250		14.9							
	432	961.3	13.1	0.97	280.3					
	500		12.6							
	750		10.9							
	1,000		9.1							
5.38	1,238	872.7	7.4	0.71	291.5					
	1,250		7.3							
	1,500		5.6							
	2,000		2.1							
5.47	2,412	755.1	-0.7	0.69	295.1					
	2,500		-0.7							
5.49	2,616	736.2	-0.7	0.00	297.2					
	3,000		-3.0							
5.53	3,205	683.6	-4.3	0.61	299.6					
	3,500		-6.1							
5.58	3,785	635.0	-7.8	0.60	302.0					
	4,000		-7.9							
6.00	4,066	612.7	-7.9	0.04	305.0					
	4,500		-11.2							
	5,000		-14.9							
	6,000		-22.5							
6.16	6,327	454.3	-25.0	0.75	310.8					
	7,000		-33.2							
6.28	7,265	398.6	-36.4	1.22	307.5					
	8,000		-40.1							
6.36	8,878	315.8	-44.5	0.50	317.7					Base of stratosphere.
	9,000		-44.5							
	10,000		-44.5							
6.46	10,261	257.9	-44.5	0.00	336.7					
	11,000		-44.8							
6.55	11,453	216.5	-45.0	0.04	353.2					
May 15, 1926, a. m.:										
6.48	225	989.5	10.8		284.7	85	11.01	ne.	3.6	1/10 cl. st., SW., and few a. cu., NE.
	250		10.5					ne.	3.6	
6.49	482	950.2	7.3	1.36	283.7			ne.	4.5	
	500		7.2					ne.	4.5	
	750		6.0					ne.	6.9	
	1,000		4.6					ne.	6.2	
	1,250		3.5					ne.	6.9	
6.55	1,405	856.9	2.7	0.50	288.2			ne.	9.4	
	1,500		2.5					ne.	11.0	
6.59	1,990	797.1	1.7	0.17	293.1			ne.	12.4	
	2,000		1.6					ne.	12.4	
	2,500		-1.7					ne.	12.2	
	3,000		-5.1					ne.	9.6	
7.05	3,007	701.4	-5.1	0.67	296.5			ne.	9.6	
	3,500		-7.5					ne.	8.4	
	4,000		-10.0					ne.	11.6	
	4,500		-12.4					ne.	11.0	
7.15	5,005	542.1	-14.9	0.49	307.5			ne.	14.4	
	6,000		-21.5							
7.25	6,697	431.7	-26.2	0.67	313.8					
	7,000		-28.1							
	8,000		-34.4							
	9,000		-40.7							
7.39	9,994	270.3	-46.9	0.63	328.7					Base of stratosphere.
	10,000		-46.9							
7.43	10,798	239.3	-48.2	0.16	338.4					
	11,000		-49.1							
7.45	11,398	218.7	-50.8	0.43	343.2					
7.48	11,886	203.7	-49.0	-0.37	353.1					
May 15, 1926, p. m.:										
6.32	225	986.5	16.2		200.3	47	8.66	w.	3.1	Few cl. st., nne. 2 a. cu., n.
	250		16.3					w.	3.6	
6.33	367	970.2	16.8	-0.42	292.3			w.	6.0	
	500		16.0					wnw.	7.5	
	750		14.4					nw.	9.8	
6.36	886	912.6	13.6	0.64	294.3			nw.	10.8	
	1,000		12.6					nw.	11.5	
	1,250		10.5					nw.	12.6	
	1,500		8.4					nnw.	12.8	
6.41	1,755	822.0	6.2	0.85	295.4			nnw.	13.5	
	2,000		4.2					nw.	15.6	
6.44	2,432	750.3	0.6	0.83	296.5			n.	14.9	
	2,500		0.2					n.	14.9	
6.48	2,891	714.0	-2.2	0.61	298.4				17.9	

TABLE 8.—Free-air data by sounding balloons, Royal Center, Ind., May, 1926—Continued

Time	Altitude	Pressure	Temperature	Δt 100 m.	Potential temperature	Humidity		Wind		Remarks
						Relative	Vapor pressure	Direction	Velocity	
May 15, 1926, p. m.:	M.	Mb.	°C.		°A.	Per cent	Mb.		M.	
6.48	3,000		-2.8					nne.	18.1	
	3,500		-5.5							
6.55	3,911	627.4	-7.8	0.55	303.3					
6.56	4,003	620.1	-7.4	-0.43	304.8					
	4,500		-10.6							
	5,000		-13.8							
	6,000		-20.2							
7.07	6,024	475.9	-20.4	0.64	312.8					
	7,000		-27.5							
	8,000		-34.8							
7.10	8,246	350.1	-36.6	0.73	319.8					
	9,000		-42.0							
	10,000		-49.1							
7.28	10,210	262.6	-50.6	0.71	326.9					
	11,000		-53.7							
7.35	11,816	205.7	-56.9	0.39	340.8					Base of strato- sphere.
	12,000		-57.0							
	13,000		-57.5							
7.41	13,008	169.8	-57.5	0.05	359.1					
May 16, 1926, p. m.:										
6.41	225	981.7	24.4		299.0	40	12.24	ws.	4.9	3/10 cl. and cl.-st., nw., and 2/10 cu., wnw.
	250		24.8					ws.	6.0	
6.42	260	977.2	25.0	-1.46	300.0			ws.	7.8	
	500		24.0					w.	12.0	
6.44	641	936.1	23.4	0.43	302.0			w.	11.2	
	750		22.4					w.	8.3	
	1,000		20.6					w.	13.1	
	1,250		17.7					w.	15.6	
	1,500		15.3					w.	17.4	
6.53	1,777	819.8	12.7	0.94	302.4			wnw.	17.1	
	2,000		10.7					wnw.	16.3	
	2,500		6.1					wnw.	14.0	
	3,000		1.5							
7.05	3,310	679.9	-1.3	0.91	303.4					
7.06	3,438	669.2	-0.9	0.31	305.2					
	3,500		-1.4							
	4,000		-5.1							
	4,500		-8.9							
	5,000		-12.7							
7.23	5,471	515.6	-16.2	0.75	310.4					
	6,000		-20.8							
	7,000		-29.4							
7.44	7,648	382.9	-35.0	0.86	313.2					
	8,000		-36.8							
7.52	8,694	330.3	-40.3	0.51	319.4					
	9,000		-43.1							
	10,000		-52.5							
8.05	10,616	247.7	-58.2	0.93	320.2					
May 18, 1926, p. m.:										
6.43	225	978.7	21.2		296.0	96	24.18	sw.	11.6	9/10 cu.-nb., WSW., and 1/10 st., SW.
	250		20.9							
	500		18.4							
	750		15.8							
6.48	820	913.2	15.1	1.03	295.7					
	1,000		14.6							
6.52	1,110	882.6	14.3	0.28	297.8					
	1,250		13.5							
	1,500		12.1							
	2,000		9.3							
6.58	2,138	780.8	8.5	0.56	302.1					
	2,500		5.8							
7.02	2,538	743.7	5.5	0.75	303.1					
	3,000		4.8							
7.07	3,164	689.1	4.5	0.16	308.7					
	3,500		3.3							
7.12	3,806	636.7	2.2	0.36	313.1					
	4,000		0.0							
7.16	4,212	605.2	-2.5	1.16	312.3					
	4,500		-4.4							
7.20	4,920	553.7	-7.2	0.66	314.4					
	5,000		-7.6							
7.22	5,217	533.1	-8.8	0.54	316.3					
	6,000		-13.8							
	7,000		-20.2							
7.33	7,401	400.0	-22.7	0.64	325.3					
	8,000		-26.7							
7.40	8,980	322.5	-33.3	0.67	331.3					
	9,000		-33.4							
	10,000		-40.2							
	11,000		-46.9							
	12,000		-53.7							
	13,000		-60.5							
	14,000		-67.1							
8.08	14,552		-70.9	0.67						Base of strato- sphere.
May 20, 1926, p. m.:										
6.08	225	985.4	17.0		291.2	40	7.75	sse.	3.1	4/10 cl. and cl.-st., WNW., and few a.-cu. and cl- cu.? very low on W. horizon.
6.09	250		17.2					sse.	4.0	
	336	972.4	17.9	-0.80	293.2			s.	6.3	
	500		16.5					s.	7.4	
	750		14.4					s.	8.8	
	1,000		12.2					s.	10.5	
	1,250		10.1					ssw.	11.0	
	1,500		7.9					ssw.	11.0	

* Altitude obtained from the ascensional rate.

TABLE 8.—Free-air data by sounding balloons, Royal Center, Ind., May, 1926—Continued

Time	Altitude	Pressure	Temperature	Δt 100 m.	Potential temperature	Humidity		Wind		Remarks
						Relative	Vapor pressure	Direction	Velocity	
May 20, 1926, p. m.:	M.	Mb.	°C.		°A.	Per cent	Mb.		M.	
6.20	1,913	805.2	4.4	0.86	295.1			ws.	12.2	
	2,000		4.8					ws.	12.2	
6.21	2,099	786.9	5.3	-0.48	298.0			ws.	11.1	
	2,500		2.9					w.	8.5	
	3,000		-0.2					w.	12.0	
	3,500		-3.2					w.	13.3	
	4,000		-6.2					wnw.	14.5	
6.36	4,013	619.8	-6.3	0.61	305.8			wnw.	14.5	
6.39	4,498	582.6	-7.8	0.31	309.5			w.	17.0	
	5,000		-11.9					w.	19.1	
6.44	5,305	524.5	-14.4	0.82	311.0			w.	19.9	
	6,000		-16.8							
6.53	6,447	451.1	-18.3	0.34	319.8					
	7,000		-22.7							
	8,000		-30.6							
	9,000		-38.6							
7.08	9,288	304.2	-40.9	0.70	326.2					
	10,000		-46.2							
7.20	11,347	223.9	-56.3	0.75	332.5					
	12,000		-59.0							
	13,000		-63.2							
7.34	13,609	157.2	-65.7	0.42	351.9					Base of strato- sphere.
	14,000		-62.5							
	14,028	147.0	-62.3	-0.82	364.6					
May 21, 1926, p. m.:										
6.39	225	976.6	16.8		291.8	92	17.61	sse.	4.0	4 nb., SW.
	250		17.0					sse.	4.0	
	405	956.2	18.3	-0.83	295.1			s.	11.3	
	500		17.7					ssw.	15.4	
	750		16.1					ssw.	22.3	
	1,000		14.5					ssw.	28.3	
	1,250		12.9					ssw.	30.6	
	1,500		11.3					ssw.	29.3	
	2,000		8.1							
	2,500		5.0							
6.53	2,655	730.6	3.9	0.64	302.9					
	3,000		2.1							
	3,500		-0.6							
	4,000		-3.3							
	4,500		-5.9							
	5,000		-8.6							
7.50	5,749	494.4	-12.6	0.53	318.5					
May 22, 1926, p. m.:										
6.37	225	991.9	9.4		283.1	70	8.25	nnw.	2.2	1/10 cl.-st., very low on N., W., and S. horizon.
	250		9.2					nnw.	2.4	
	500		7.5					nnw.	3.5	
	750		5.8					nnw.	5.3	
6.43	825	992.1	5.3	0.68	284.8			nnw.	6.7	
	1,000		3.9					nnw.	9.9	
	1,250		2.0					nnw.	13.3	
	1,500		0.1					nnw.	15.5	
6.52	1,765	820.8	-2.0	0.78	286.7			nnw.	16.8	
	2,000		-1.3					nnw.	16.0	
6.58	2,411	756.9	0.0	-0.31	295.6			nnw.	18.1	
	2,500		-0.8					nnw.	17.0	
	3,000		-5.1					nnw.	15.6	
7.09	3,383	669.1	-8.4	0.86	296.8			nnw.	19.6	
May 23, 1926, p. m.:										
6.00	225	989.2	16.7		290.6	53	10.08	s.	3.1	Few cu.? along NE. horizon.
	250		16.5					s.	3.2	
	500		14.2					s.	10.0	
	750		12.0					ssw.	12.3	
	1,000		9.8					ssw.	15.1	
6.17	1,107	890.6	8.8	0.90	291.3			ssw.	13.6	
	1,250		9.8					ssw.	13.9	
6.2										

TABLE 8.—Free-air data by sounding balloons, Royal Center, Ind., May, 1926—Continued

Time	Altitude	Pressure	Temperature	Δt 100 m.	Potential temperature	Humidity		Wind		Remarks
						Relative	Vapor pressure	Direction	Velocity	
May 24, 1926, p. m.:	M.	Mb.	° C.		° A.	Per cent	Mb.		M.	
6.34	1,250	880.4	18.5	0.26	303.9			wnw.	5.0	
6.43	1,413	860.4	18.1					wnw.	9.2	
	1,500		17.4					wnw.	9.8	
	2,000		13.2					w.	12.4	
	2,500		9.0					wnw.	11.6	
6.55	2,860	724.0	6.0	0.84	306.0					
	3,000		5.1							
	3,500		2.1							
	4,000		-1.0							
	4,500		-4.0							
	5,000		-7.1							
7.19	5,767	502.5	-11.8	0.61	318.0					Clock stopped.
May 25, 1926, p. m.:										
6.25	225	985.8	24.0		298.2	87	25.98	ene.	6.3	4 a. cu., WNW, and 4 cu., WSW.
	250		23.8					ene.	8.3	
6.27	468	958.8	22.4	0.66	299.0			e.	9.9	
	500		22.5					e.	8.4	
	750		23.1					s.	2.4	
6.30	871	915.5	23.4	-0.25	304.0			sw.	3.6	
	1,000		22.6					sw.	5.5	
	1,250		21.0					w.	8.0	
	1,500		19.4					w.	9.8	
	2,000		16.1					sw.	11.8	
6.41	2,185	786.0	14.9	0.65	308.4			w.	12.5	
	2,500		11.1					w.	12.2	
6.48	2,981	714.3	5.2	1.22	306.3			w.	13.0	
	3,000		5.1					w.		
	3,500		3.5							
6.54	3,668	657.0	3.0	0.32	311.2					
	4,000		0.3							
	4,500		-3.6							
7.02	4,657	581.1	-4.9	0.80	313.1					
	5,000		-6.6							
7.13	5,840	499.5	-10.7	0.49	319.9					
	6,000		-11.9							
	7,000		-19.5							
	8,000		-27.1							
	9,000		-34.7							
7.45	9,036	325.1	-35.0	0.76	328.2					
	10,000		-42.2							
	11,000		-49.7							
8.16	11,059	242.7	-50.3	0.76	333.9					
May 26, 1926, p. m.:										
6.20	225	987.5	16.0		290.0	90	18.01	ene.	8.5	10/10 st., ENE.
	250		15.5							
	500		10.8							
6.24	558	949.1	9.7	1.89	287.0					
6.25	683	935.1	14.5	-3.84	293.1					
	750		14.5							
	1,000		14.6							
	1,250		14.7							
	1,500		14.8							
6.35	1,733	826.2	14.9	-0.04	304.1					
	2,000		13.1							
	2,500		9.7							
6.43	2,773	729.5	7.8	0.68	307.3					
	3,000		5.9							
	3,500		1.6							
	4,000		-2.6							
7.01	4,306	603.2	-5.2	0.85	309.5					
May 27, 1926, p. m.:										
5.53	225	993.2	21.8		295.4	57	14.90	ene.	6.3	2/10 cl. st., N.
	250		21.6					ene.	6.3	
	500		19.7					e.	8.9	
	750		17.7					e.	12.0	
	1,000		15.8					e.	12.0	
6.00	1,052	902.0	15.4	0.77	297.0			e.	12.4	
	1,250		14.8					e.	13.1	
	1,500		14.2					e.	12.4	
	2,000		12.8					e.	6.7	
	2,500		11.4					ene.	3.4	
6.16	2,882	725.3	10.3	0.28	310.6			nw.	2.9	
	3,000		9.7					nw.	2.8	
	3,500		7.0					ene.	2.6	
	4,000		4.3					nne.	2.0	
	4,500		1.6					ene.	2.3	
	5,000		-1.1					ene.	4.0	
6.38	5,192	546.4	-2.1	0.54	322.0			ne.	3.3	
	6,000		-7.6					n.	3.4	
6.47	6,231	478.9	-9.2	0.68	325.6			nw.	2.9	
6.54	6,907	438.8	-12.7	0.52	329.4			nne.	9.0	
	7,000		-13.5					nne.	7.5	
	8,000		-21.8							
	9,000		-30.2							
7.17	9,437	311.8	-33.8	0.83	333.8					
	10,000		-38.0							
	11,000		-45.3							
7.32	11,252	240.6	-47.2	0.74	339.4					
	12,000		-53.0							
7.46	12,978	185.6	-60.5	0.77	344.0					

TABLE 8.—Free-air data by sounding balloons, Royal Center, Ind., May, 1926—Continued

Time	Altitude	Pressure	Temperature	Δt 100 m.	Potential temperature	Humidity		Wind		Remarks
						Relative	Vapor pressure	Direction	Velocity	
May 28, 1926, p. m.:	M.	Mb.	° C.		° A.	Per cent	Mb.		M.	
6.27	225	994.9	19.9		293.3	57	13.25	e.	2.7	3/10 a. cu., NNW.
	250		19.7					e.	4.0	
	500		17.8					e.	7.6	
	750		15.8					e.	7.4	
	1,000		13.9					ene.	6.5	
6.38	1,187	888.6	12.4	0.78	295.2			ene.	6.4	
	1,250		12.5					se.	5.3	
6.42	1,498	856.2	12.9	-0.16	298.9			se.	1.8	
6.45	1,812	824.7	11.0	0.61	300.1			s.	3.6	
	2,000		11.6					sw.	3.7	
6.48	2,075	798.4	11.9	-0.34	303.8			sw.	3.0	
	2,500		9.2					nw.	2.9	
	3,000		6.1					wnw.	1.8	
	3,500		2.9					se.	1.3	
7.05	3,517	671.0	2.8	0.63	309.1			se.	1.3	
	4,000		-0.3					se.	3.1	
	4,500		-3.4					ene.	2.5	
	5,000		-6.6					nne.	2.7	
7.25	5,315	636.1	-8.6	0.64	316.2			nne.	4.0	
	6,000		-13.1					n.	4.5	
	7,000		-19.7							
7.45	7,132	421.9	-20.6	0.66	323.1					
	8,000		-26.4							
	9,000		-33.1							
8.08	9,098	322.7	-33.7	0.67	330.7					
	10,000		-40.1							
8.24	10,600	259.9	-44.3	0.70	336.2					
	11,000		-47.5							
8.33	11,433	229.5	-50.9	0.79	338.4					
May 29, 1926, p. m.:										
5.59	225	990.9	24.4		298.2	56		se.	2.7	1/10 a. st. Very low on E. horizon.
	250		24.5					se.	2.8	
6.01	460	964.7	25.1	-0.30	301.2			se.	5.4	
	500		24.8					se.	5.5	
	750		22.8					se.	6.0	
	1,000		20.9					se.	6.9	
	1,250		18.9					s.	7.4	
6.11	1,300	875.8	18.5	0.79	302.8			s.	7.1	
	1,500		17.8					s.	4.0	
6.17	1,748	831.0	17.0	0.34	305.8			wnw.	3.3	
	2,000		15.3					nw.	4.1	
	2,500		11.9					nw.	5.4	
	3,000		8.5					wnw.	5.6	
6.39	3,106	707.0	7.8	0.68	310.1			wnw.	6.1	
	3,500		4.8					w.	5.9	
	4,000		1.1					w.	5.6	
6.58	4,201	618.0	-0.4	0.75	312.8			w.	7.8	
May 30, 1926, p. m.:										
6.25	225	987.1	26.8		300.9	60	24.34	sw.	2.7	1/10 cl. st., very low on S. horizon.
	250		26.0					sw.	3.2	
	500		24.5					sw.	7.7	1/10 cu. nb., W., and 6/10 st. cu., WSW.
	750		22.4					sw.	7.0	
6.35	1,169	886.0	18.8	0.85	302.1			sw.	7.9	
	1,250		18.2					sw.	8.3	
	1,500		16.4					sw.	8.7	
	2,000		12.7					sw.	9.6	
6.48	2,339	771.6	10.2	0.74	305.6					
	2,500		9.5							
	3,000		7.2							
	3,500		5.0							
7.00	3,986	631.6	2.8	0.45	314.5					
	4,000		2.7							
	4,500		-0.4							
	5,000		-3.5							
7.20	5,139	547.2	-4.4	0.62	319.2					
	6,000		-10.0							
	7,000		-16.4							
7.48	7,742	390.3	-21.2	0.65	320.5					
	8,000		-23.4							
	9,000		-31.7							
8.11	9,679	299.2	-37.4	0.84	332.7					
	10,000		-40.2							
	11,000		-48.8							
8.54	11,216	239.2	-50.6	0.86	334.8					

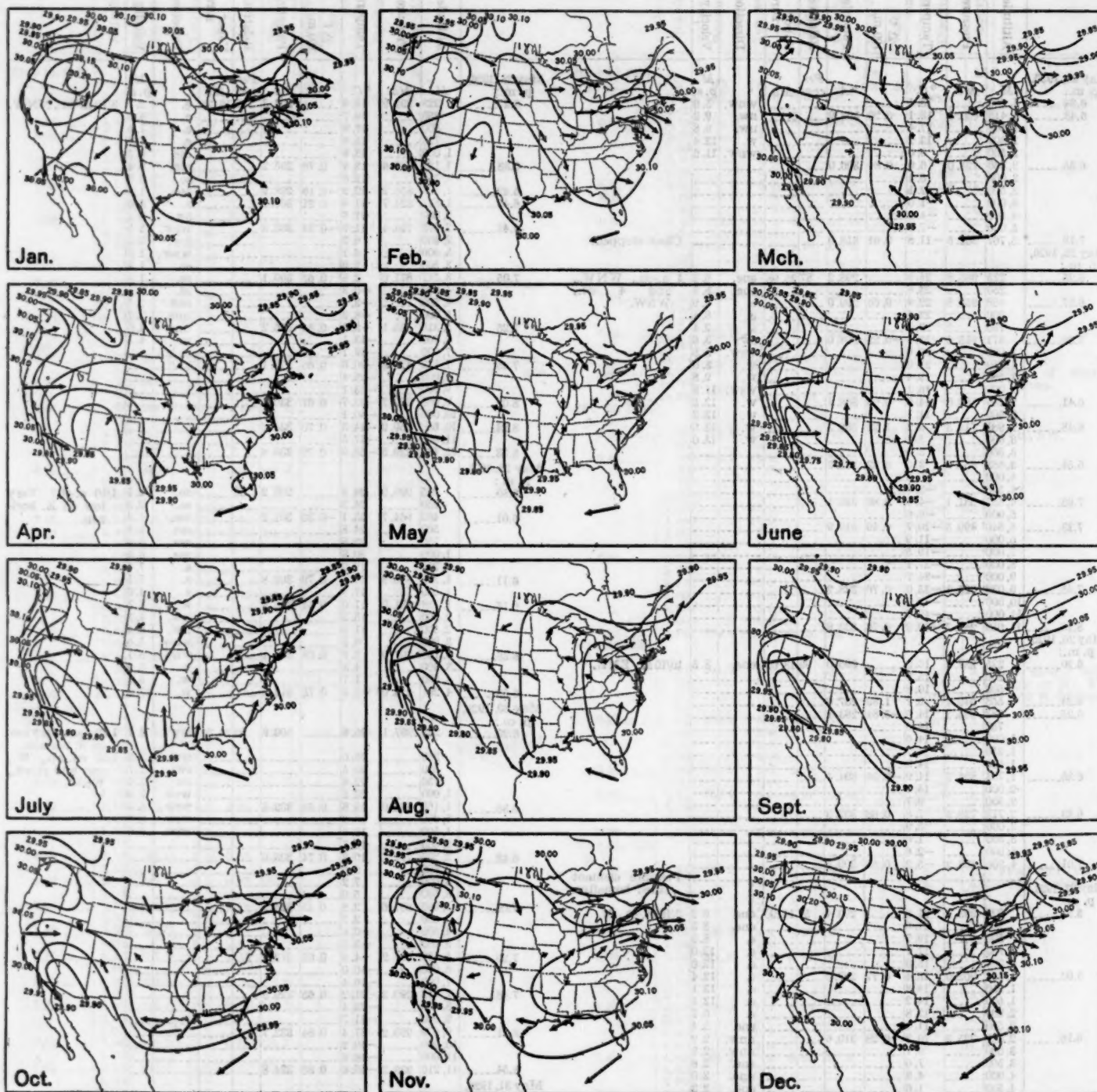
MONTHLY CHARTS OF FREQUENCY-RESULTANT WINDS IN THE UNITED STATES

By ERIC R. MILLER

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The object of this paper is to present to the readers of the MONTHLY WEATHER REVIEW a set of tables and

Chief of the Weather Bureau for the 13 years, 1891 to 1902, inclusive. In these reports were given the "num-



FIGS. 1-12, INCLUSIVE.—Frequency-resultant winds in the United States for each of the 12 months

charts of wind frequency and frequency resultants for the United States.

The data from which these charts and tables were computed were published in the annual reports of the

ber of hours that the wind blew from each of the eight directions, N., NE., etc., for 28 cities. The data are complete for the 13 years, except at four cities, and at these the record covers more than 12 years.

It has not appeared possible to apply any corrections to the data. The directions are recorded automatically, all directions within $22\frac{1}{2}^\circ$ on either side of N., NE., etc., being recorded as N., NE., etc. This introduces an error that has been discussed by Werenskiold (1). The wind vanes varied in elevation at different stations from 29 feet to 350 feet, and were changed as the stations were moved from building to building with the growth of cities. At the 28 stations no less than 71 different locations were occupied by the anemometers, and only 5 remained in the same location throughout the 13-year period.

Since the average velocity corresponding to each component is not given in the tables, these have been assumed to be equal, and the different directions were weighted only in proportion to their frequency. The frequency resultant has been studied analytically by Terada (2) and empirically by Abbe (3), who has published comparative tables of monthly frequency resultants and ordinary resultants for the 13 months from December, 1893, to December, 1894, inclusive.

The method of computing the frequency resultants has been fully illustrated in the MONTHLY WEATHER REVIEW by Davis (4) and is equivalent to Lambert's formula. This was applied to the percentages of time that the wind blew from each direction in each month and in each of the 28 cities. These percentages and the frequency resultants computed from them are given in Table 1. The frequency resultants have been charted and appear in Figures 1 to 12, inclusive, on page 308. To these charts have been added the monthly sea-level isobars from Bigelow (5).

In interpreting these charts it is to be remembered that the computation has retained only the excess of opposing winds. Hence a small resultant does not mean that there is little wind, but that the winds from opposite direction prevail for nearly equal periods. The symmetric components of cyclones and anticyclones have been eliminated, so that the chief effect of this work has been the elimination of the cyclonic and anticyclonic whirls.

The seasonal or annual march of the resultant winds is brought out in Figure 13, in which the annual march of the resultants at 9 of the 28 cities have been graphed by first drawing the successive monthly resultants from the same initial point, then connecting the final points of the resultants in monthly sequence. Finally all of the resultants, except January, were erased. The direction north is shown by an arrow at the initial point.

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- (5) BIGELOW, F. H. Rept. on the barometry of the U. S., etc. Rept. Chief of the Weather Bureau, 1900-1901, vol. 2, Chart 28, following page 638.

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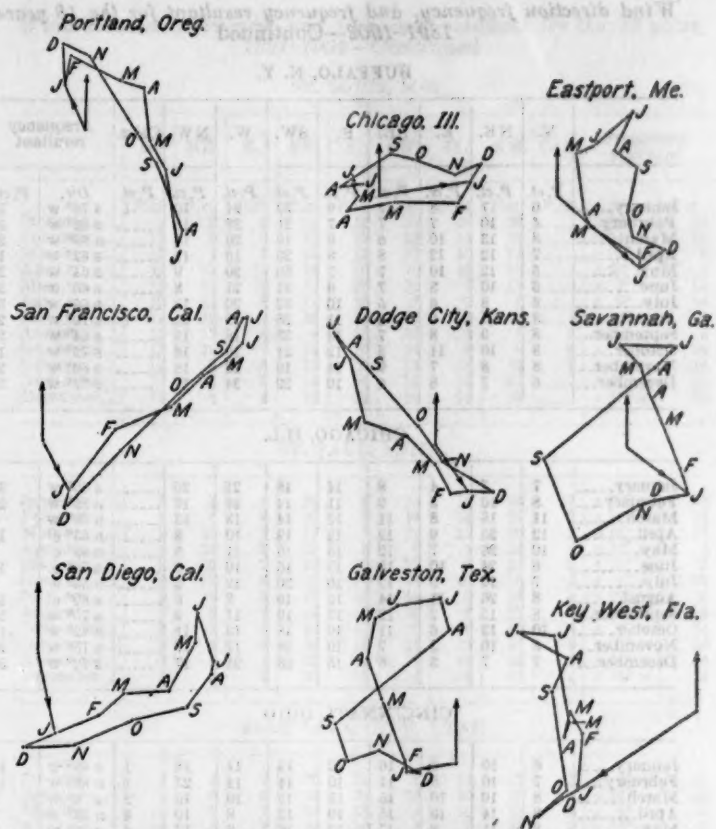


FIG. 13.—The annual march of the frequency resultant at nine cities of the United States, shown by the path of the end of the wind-resultant vectors for the successive months. The base of the vertical arrow is the origin of the resultants. Only the January resultant is drawn. The letters are the initials of the months.

Wind direction frequency, and frequency resultant for the 13 years, 1891-1902

BISMARCK, N. DAK.

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Frequency resultant
	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	Dir. P. ct.
January.....	10	5	11	10	6	3	7	45	4	n 32° w 36
February.....	9	6	9	11	5	4	8	44	3	n 32° w 36
March.....	14	10	14	12	6	5	5	31	3	n 2° w 24
April.....	15	10	16	20	7	4	4	21	2	n 52° e 20
May.....	12	11	19	19	9	3	5	21	1	n 62° e 21
June.....	13	8	12	17	11	6	8	23	1	n 8° e 8
July.....	12	9	14	17	12	5	6	22	2	n 53° e 11
August.....	14	10	16	16	12	4	6	19	2	n 56° e 14
September.....	12	6	12	15	10	5	6	32	2	n 21° w 15
October.....	11	5	12	12	8	6	8	36	3	n 33° w 25
November.....	10	7	13	13	8	5	5	37	2	n 22° w 22
December.....	10	4	10	10	6	5	10	42	4	n 41° w 35

BOSTON, MASS.

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Frequency resultant
	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	Dir. P. ct.
January.....	12	4	4	4	6	17	27	25	-----	n 70° w 53
February.....	10	8	6	3	6	13	30	24	-----	n 71° w 44
March.....	8	9	10	5	7	15	24	22	-----	n 73° w 31
April.....	9	14	14	5	7	15	21	16	-----	n 57° w 19
May.....	6	13	16	5	10	20	17	13	-----	n 76° w 11
June.....	6	11	16	4	7	25	21	10	-----	n 72° w 20
July.....	4	7	14	4	8	30	21	11	-----	n 81° w 32
August.....	8	7	16	7	9	22	20	13	-----	n 68° w 20
September.....	8	9	12	5	8	22	20	16	-----	n 89° w 26
October.....	10	11	8	4	8	20	20	19	-----	n 76° w 30
November.....	11	7	5	4	7	19	23	23	-----	n 74° w 32
December.....	11	4	4	4	6	22	28	22	-----	n 84° w 50

Wind direction frequency, and frequency resultant for the 13 years,
1891-1902—Continued

BUFFALO, N. Y.

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Frequency resultant
	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	Dir.
January.....	6	7	8	7	9	22	24	16	1	s 76° w
February.....	4	10	7	7	7	21	27	16	—	s 82° w
March.....	8	13	10	6	9	19	20	14	—	n 89° w
April.....	7	12	12	8	8	26	16	11	—	s 62° w
May.....	5	12	10	7	7	30	20	9	—	s 64° w
June.....	6	10	8	7	9	31	21	8	—	s 60° w
July.....	8	8	6	5	10	32	20	11	—	s 65° w
August.....	8	11	9	6	11	25	19	11	1	s 70° w
September.....	8	9	8	7	13	23	18	12	—	s 64° w
October.....	8	10	11	8	12	21	16	16	—	s 72° w
November.....	8	8	7	9	11	19	22	18	—	s 80° w
December.....	6	7	8	6	10	22	24	17	—	s 77° w

CHICAGO, ILL.

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Frequency resultant
	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	Dir.
January.....	7	7	4	8	14	18	21	20	—	s 80° w
February.....	8	10	5	9	11	14	24	19	—	s 86° w
March.....	11	18	8	11	12	14	13	13	—	n 67° w
April.....	12	25	9	12	12	12	10	8	—	s 65° e
May.....	10	26	7	12	13	16	11	5	—	n 89° e
June.....	8	24	10	13	13	16	10	6	—	s 70° e
July.....	7	24	9	12	10	20	12	6	—	s 65° e
August.....	8	26	11	14	12	16	8	6	—	s 80° e
September.....	8	15	7	12	18	19	11	9	—	s 76° w
October.....	10	13	6	11	19	18	13	11	—	s 42° w
November.....	8	10	3	7	19	18	17	17	—	s 75° w
December.....	7	7	3	6	15	23	21	17	—	s 72° w

CINCINNATI, OHIO

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Frequency resultant
	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	Dir.
January.....	6	10	9	16	10	19	11	18	1	s 45° w
February.....	7	10	8	14	10	14	14	23	1	n 86° w
March.....	8	10	10	15	11	15	10	19	2	s 1° w
April.....	8	14	10	15	10	13	8	19	4	n 23° w
May.....	8	11	8	17	12	16	8	17	4	s 23° w
June.....	8	12	9	18	11	18	7	12	0	s 10° e
July.....	7	9	9	16	12	21	9	12	6	s 21° w
August.....	9	14	11	17	11	14	7	12	5	s 59° e
September.....	8	12	12	21	8	14	7	12	5	s 47° e
October.....	8	11	11	22	9	13	8	15	3	s 45° e
November.....	6	8	8	11	12	17	10	17	2	s 54° w
December.....	5	8	6	10	13	20	10	15	2	s 26° w

CLEVELAND, OHIO

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Frequency resultant
	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	Dir.
January.....	5	6	4	20	15	23	15	13	—	s 34° w
February.....	8	8	2	19	11	19	18	15	—	s 60° w
March.....	11	13	4	20	10	13	15	14	—	s 63° w
April.....	14	12	5	18	8	11	16	16	—	n 64° w
May.....	15	13	4	18	12	12	11	15	—	n 64° w
June.....	14	13	5	20	13	11	12	12	—	s 15° w
July.....	16	9	4	18	16	11	11	14	—	s 53° w
August.....	16	12	7	22	12	9	9	14	—	n 82° e
September.....	12	10	5	28	13	11	9	12	—	s 13° e
October.....	8	8	5	29	14	15	9	12	—	s 7° e
November.....	4	6	2	26	17	21	12	12	—	s 18° w
December.....	4	6	2	22	19	26	12	9	—	s 23° w

DETROIT, MICH.

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Frequency resultant
	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	Dir.
January.....	7	9	5	5	9	32	21	13	—	s 72° w
February.....	7	14	6	5	6	27	22	15	—	s 89° w
March.....	6	21	10	8	5	22	14	13	—	n 69° w
April.....	10	21	11	10	6	18	12	13	—	n 3° w
May.....	8	19	11	8	7	24	12	10	—	s 84° w
June.....	7	17	12	8	8	26	15	8	—	s 53° w
July.....	9	15	10	5	7	29	14	11	—	s 69° w
August.....	10	18	10	12	7	23	11	9	1	s 52° w
September.....	9	13	7	12	9	26	13	10	—	s 51° w
October.....	9	13	8	9	10	24	14	13	—	s 71° w
November.....	8	9	3	7	9	28	19	16	—	s 77° w
December.....	8	8	3	6	8	37	18	12	—	s 57° w

DODGE, KANS.

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Frequency resultant
	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	Dir.
January.....	16	12	3	15	10	8	9	26	1	n 46° w
February.....	17	14	3	16	10	7	7	25	—	n 16° w
March.....	15	14	4	18	14	8	5	22	—	n 2° w
April.....	12	12	6	26	14	7	3	20	1	s 72° e
May.....	12	19	6	26	18	6	2	10	1	s 72° e
June.....	8	14	6	37	22	6	2	5	—	s 46° e
July.....	5	12	6	42	24	4	1	4	—	s 43° e
August.....	8	12	6	37	25	5	2	4	9	s 43° e
September.....	9	14	5	31	28	5	3	5	1	s 42° e
October.....	13	13	4	22	30	7	6	14	1	s 44° e
November.....	17	12	3	19	14	8	7	20	1	n 16° w
December.....	16	8	2	12	11	9	12	28	1	n 52° w

Wind direction frequency, and frequency resultant for the 13 years,
1891-1902—Continued

EASTPORT, ME.

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Frequency resultant
	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	Dir.
January.....	19	11	4	6	3	12	22	23	1	n 49° w
February.....	15	12	5	4	5	12	23	23	1	n 53° w
March.....	15	11	7	6	8	17	18	17	1	n 49° w
April.....	16	14	10	5	12	15	15	10	2	n 52° w
May.....	12	12	9	5	23	19	10	7	3	s 26° w
June.....	10	13	6	4	21	25	11	6	3	s 40° w
July.....	10	6	3	3	23	27	13	7	3	s 43° w
August.....	12	9	5	4	22	22	14	8	5	s 53° w
September.....	13	7	6	4	16	24	17	12	2	s 69° w
October.....	17	9	5	4	11	20	16	15	3	n 77° w
November.....	16	12	4	5	7	17	19	18	1	n 62° w
December.....	16	8	3	4	5	16	24	23	1	n 64° w

GALVESTON, TEX.

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Frequency resultant
	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	Dir.
January.....	15	15	12	20	12	8	4	14	1	n 81° e
February.....	14	15	11	21	14	8	4	12	—	s 85° e
March.....	10	12	9	31	19	8	2	8	—	s 49° e
April.....	6	8	10	39	22	7	2	6	—	s 40° e
May.....	5	6	5	41	29	8	2	3	—	s 29° e
June.....	3	6	5	36	31	14	3	2	—	s 20° e
July.....	3	4	5	27	33	21	4	3	—	s 5° e
August.....	4	6	6	21	30	21	6	4	—	s 2° e
September.....	9	18	16	32	13	5	2	4	—	s 82° e
October.....	10	21	17	26	8	6	2	8	—	s 89° e
November.....	12	17	14	23	13	8	3	9	—	s 81° e
December.....	15	15	11	18	14	7	6	14	—	n 76° e

HAVRE, MONT.

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Frequency resultant
	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	Dir.
January.....	5	15	4	0	0	34	24	13	3	n 90° w
February.....	4	19	5	1	1	29	25	13	3	n 82° w
March.....	6	23	10	1	1	24	19	13	3	n 64° w
April.....	7	18	11	4	2	22	19	15	2	n 62° w
May.....	5	15	16	7	3	20	19	13	2	n 71° w
June.....	8	14	9	5	3	22	22	14	2	n 78° w
July.....	9	13	11	4	3	21	21	15	3	n 72° w
August.....	8	20	10	4	4	19	18	15	2	n 62° w
September.....	6	14	8	2	3	25	23	17	2	n 79° w
October.....	6	12	7	3	2	32	24	11	3	s 83° w
November.....	6	15	6	1	1	34	23	13	2	s 90° w
December.....	4	15	5	1	0	39	22	11	3	s 81° w

KANSAS CITY, MO.

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Frequency resultant
	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	Dir.
January.....	14	8	6	13	14	14	6	26	—	n 75° w
February.....	16	11	8	12	11	10	8	25	—	n 33° w
March.....	13	13	7	16	12	12	4	23	—	n 23° w
April.....	12	11	11	22	13	10	4	16	—	s 72° e
May.....	14	15	7	21	18	9	4	11	—	s 65° e
June.....	10	13	8	25	21	10	2	9	1	s 63° e
July.....	12	14	8	23	22	11	2	7	1	s 45° e
August.....	12	16	9	24	20	9	2	8	1	s 58° e
September.....	12	11	6	26	23	10	3	9	—	s 38° e
October.....	12	8	4	23	18	13	4	16	1	s 8° e
November.....	13	8	5	18	17	12	4	22	—	s 58° w
December.....	14	9	3	12	16	15	6	24	—	n 82° w

KEY WEST, FLA.

	N.	NE.	E.	SE.	S.	SW.
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Wind direction frequency, and frequency resultant for the 13 years;
1891-1902—Continued

ST. LOUIS, MO.

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Frequency resultant	
	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	P.ct.	Dir.	P.ct.
January.....	9	9	5	13	18	11	16	20	-----	s 75° w	16
February.....	13	9	6	12	13	11	15	21	-----	n 74° w	18
March.....	12	9	9	16	15	11	13	17	-----	s 59° w	17
April.....	12	11	11	18	16	10	10	12	-----	s 38° e	14
May.....	13	11	7	15	23	12	9	11	-----	s 1° w	16
June.....	10	11	8	11	26	17	9	8	-----	s 9° w	24
July.....	11	12	7	10	24	18	9	9	-----	s 16° w	19
August.....	15	17	8	9	21	14	8	8	1	s 28° e	6
September.....	13	10	7	14	26	14	6	9	1	s 3° e	18
October.....	13	8	5	13	27	11	10	13	1	s 25° w	18
November.....	12	5	5	14	25	10	12	17	-----	s 42° w	18
December.....	12	6	4	12	22	14	14	17	-----	s 37° w	23

ST. PAUL, MINN.

January.....	5	3	4	23	8	13	14	29	2	s 72° w	23
February.....	5	6	4	20	8	14	15	28	2	s 82° w w	23
March.....	8	10	7	19	7	11	11	26	1	n 66° e	23
April.....	8	12	9	22	8	9	8	22	2	n 66° e	2
May.....	8	12	7	21	10	12	8	21	2	s 16° w	4
June.....	5	6	6	30	11	14	10	16	2	s 1° e	19
July.....	7	5	5	23	13	16	9	19	3	s 27° w	13
August.....	7	5	6	24	13	12	8	21	4	s 6° w	13
September.....	6	5	5	28	13	13	10	16	4	s 6° w	23
October.....	5	4	4	26	11	14	12	21	4	s 33° w	13
November.....	6	4	4	23	10	12	14	25	2	s 64° w	13
December.....	5	3	4	22	10	14	14	27	1	s 70° w	23

SALT LAKE CITY, UTAH

January.....	4	4	9	26	15	9	14	17	3	s 3° w	21
February.....	6	6	8	24	14	10	12	19	2	s 14° w	14
March.....	10	7	7	24	13	6	10	22	1	s 4° w	7
April.....	10	8	8	23	10	7	9	24	2	n 53° w	3
May.....	9	9	9	23	10	6	7	24	2	n 54° w	3
June.....	11	11	10	25	10	6	5	23	1	n 71° e	10
July.....	9	11	11	28	12	5	5	19	-----	s 71° e	17
August.....	6	9	10	32	14	6	5	17	-----	s 49° e	24
September.....	7	10	10	31	10	5	6	21	1	s 55° e	17
October.....	7	8	10	30	9	4	8	22	2	s 61° e	10
November.....	6	5	8	33	12	7	9	18	2	s 24° e	20
December.....	6	5	8	33	12	9	10	16	2	s 18° e	23

SAN DIEGO, CALIF.

January.....	15	20	8	6	5	8	12	22	6	n 13° w	30
February.....	11	16	6	5	6	11	18	24	4	n 45° w	32
March.....	9	12	5	5	6	14	22	24	4	n 66° w	35
April.....	8	7	3	3	5	16	28	27	4	n 74° w	57
May.....	5	3	1	3	9	25	28	24	2	s 86° w	56
June.....	5	2	1	2	10	31	26	19	4	s 76° w	58
July.....	6	1	0	1	5	26	27	28	4	n 88° w	64
August.....	6	1	0	1	4	22	30	29	6	n 84° w	66
September.....	9	3	1	2	5	15	23	36	5	n 71° w	57
October.....	13	9	3	4	6	11	18	30	6	n 56° w	42
November.....	16	18	7	5	5	7	12	26	5	n 22° w	36
December.....	13	26	11	5	6	5	9	21	4	n 9° e	34

SAN FRANCISCO, CALIF.

January.....	23	7	5	17	7	9	11	30	1	n 29° w	20
February.....	13	6	3	15	9	16	24	13	1	s 50° w	28
March.....	8	4	3	9	8	22	35	10	1	s 78° w	46
April.....	4	2	2	7	7	32	40	7	1	s 63° w	64
May.....	2	2	1	4	6	38	42	4	-----	s 67° w	75
June.....	1	1	1	3	4	45	44	1	-----	s 64° w	81
July.....	0	1	0	1	5	56	36	0	-----	s 59° w	86
August.....	0	1	0	1	7	53	37	0	-----	s 50° w	96
September.....	2	1	1	4	6	40	42	3	1	s 65° w	76
October.....	7	3	2	7	8	28	37	7	2	s 71° w	56
November.....	17	5	4	12	8	15	23	15	2	n 53° w	26
December.....	28	8	5	15	7	8	10	19	-----	n 17° w	28

SANTA FE, N. MEX.

January	14	31	6	13	7	11	4	11	4	n 42° e	27
February	14	22	5	12	7	15	5	16	4	n 13° e	18
March	10	14	5	14	9	20	7	20	3	n 56° e	10
April	8	11	7	20	9	22	6	15	2	s 17° e	12
May	6	11	8	21	10	25	6	11	2	s 2° e	12
June	5	10	9	26	10	26	5	9	2	s 9° e	26
July	7	13	11	23	11	17	5	9	4	s 39° e	22
August	7	13	12	25	10	16	5	9	3	s 45° e	24
September	6	11	9	26	12	18	5	9	4	s 27° e	16
October	8	14	8	25	9	18	4	10	4	s 38° e	18
November	13	22	7	19	6	14	4	12	5	n 63° e	16
December	15	30	5	13	6	10	4	12	4	n 33° e	28

Wind direction frequency, and frequency resultant for the 13 years, 1891-1902—Continued

SAVANNAH, GA.

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Frequency resultant
	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	Dir. P. ct.
January	12	15	6	4	7	15	18	20	—	n 54° w 28
February	10	13	7	7	10	15	17	20	—	n 70° w 21
March	8	10	9	10	18	16	13	16	—	s 45° w 18
April	8	8	9	12	23	14	13	12	—	s 22° w 20
May	6	8	9	15	25	17	12	8	1	s 8° w 30
June	6	8	10	18	25	20	9	4	—	s 4° e 37
July	6	7	6	12	21	30	13	5	1	s 27° w 41
August	7	9	8	12	22	24	12	7	1	s 20° w 31
September	11	26	17	15	11	8	6	4	1	n 83° e 31
October	20	29	11	8	6	5	7	12	—	n 29° e 38
November	17	18	8	8	8	11	12	17	1	n 14° w 20
December	16	16	8	7	9	12	13	18	—	n 29° w 21

Wind direction frequency, and frequency resultant for the 13 years, 1891-1902—Continued

WASHINGTON, D. C.

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calm	Frequency resultant
	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	Dir. P. ct.
January	12	11	5	6	18	7	10	28	3	n 52° w 21
February	14	11	5	6	14	7	10	30	2	n 44° w 28
March	13	13	8	8	17	5	8	27	2	n 29° w 17
April	11	12	7	11	18	6	8	26	2	n 45° w 14
May	10	12	8	10	25	8	8	18	2	s 26° w 7
June	12	11	6	10	24	11	9	16	2	s 47° w 11
July	9	8	5	9	29	12	10	16	3	s 36° w 21
August	14	12	7	9	23	8	8	16	4	s 50° w 3
September	13	13	9	10	21	9	7	15	3	s 61° e 3
October	14	15	6	7	18	6	8	23	4	n 26° w 15
November	13	9	4	6	23	6	9	28	3	n 71° w 20
December	13	7	4	6	22	8	11	26	3	n 89° w 27

THE DEPENDENCE OF COASTAL SEA TEMPERATURES OF CAPE COD ON THE WEATHER

By FRANCES VANDERVOORT TRIPP

The purpose of this study is to ascertain the temperatures of the ocean water surrounding Cape Cod and to discover

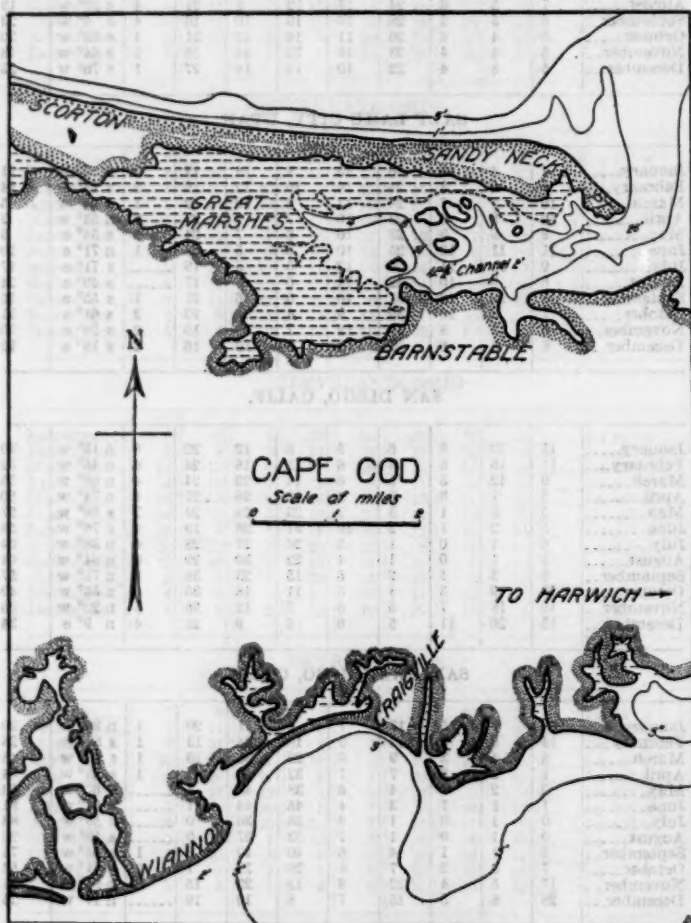


FIG. 1.—Map of Barnstable and vicinity

to what extent the agents, sun, wind and air affect these temperatures. Observations were made at six stations during the summers of 1925 and 1926, three located on the north, three on the south side of the cape. (See map, fig. 1.) Of those on the north side, the first, Barnstable, is situated on Barnstable Harbor, where the tidal rise and fall is between 9 and 10 feet; the second, Sandy Neck Point, forms the entrance to Barnstable Harbor; the third, Scorton Dunes, is located on the outside of Sandy Neck.

All three have deep water at high tide, the first two have exposed flats at low tide. At the fourth station, Craigville, on the south shore, the rise and fall of tide is negligible, the water is always deep; while at the fifth and sixth stations, Harwich and Wianno, with the exception of flood tide, the water is never deep. Conditions at Harwich and Wianno being similar, data from these two stations may be grouped together.

To obtain the water temperatures, a Fahrenheit thermometer was placed inside a heavily weighted ginger-ale bottle which was lowered into the water by a 5-foot string attached near its mouth. After it had filled at that depth it was raised and the thermometer read. All temperature readings not made at that depth are so designated. The time required for the bottle to sink was 4 seconds, required to sink and fill, 22 seconds, required to fill just below the surface, also 22 seconds. The bottle was one-sixth full on reaching the bottom. Owing to the great rise and fall of tide and consequent rapidly moving water in Barnstable Harbor, where most of the observations were taken, the difference in temperature between the surface and 5 feet is in a majority of cases negligible.

Because of the contour of the coast line and its relation to the cold drift from the north, the water along the sandy shores of Cape Cod falls naturally into four divisions: (1) North shore, deep; (2) north shore, shallow; (3) south shore, deep; (4) south shore, shallow. The average summer temperature of the north shore deep ranges from 63° to 66° (the higher figure being found where sunned flats have influence); the average summer temperature of the south shore, deep, remains fairly constant at 74°-75°. Shallow-water temperatures vary more, depending on the interrelation of the factors, sun, wind, and air. To determine the sequence in importance of these factors in influencing local shore temperatures, high-tide temperatures at Barnstable (deep water, north shore, influenced somewhat by sunned flats) will be considered in relation to each factor in turn.

INSOLATION

The greatest number of high-water temperatures came on clear or hazy days; 22 examples of water at 70°-75° occurring on such days, against 14 on partly cloudy and cloudy days. The lowest temperatures and the greatest number of temperatures below 65° were recorded on partly cloudy and cloudy days; there were 16 instances of water 59°-65° on such days, against 11 on clear days. Water below 65° on clear days was due in practically all cases either to an exceptionally strong offshore wind or

to the chilly northeast wind which prevailed August 15–September 15, 1926. The average water temperature on clear and hazy days, as shown by 78 observations, was 67.6°; on partly cloudy and cloudy days, as shown by 45 observations, was 66.6°, a difference of 1°.

The lag in the effect of cloudiness is shown in the table next following. Table 2 illustrates the steady fall in water temperature in cloudy weather, wind and air conditions being similar.

The following table shows that the effect of cloudiness is felt 24 hours later rather than on the day it occurs.

TABLE 1.—Water temperature and cloudiness at Barnstable

Date	Sky	Temperature		Water 24 hours later
		Air	Water	
1926				
July 14.....	Cloudy.....	° F. 59	° F. 68	° F. 64
30.....	do.....	70	68.8	64
Aug. 5.....	do.....	70	72	68
18.....	do.....	64	68	65
19.....	do.....	64	65	62
25.....	do.....	68	65	61.8
Sept. 2.....	do.....	60.5	64	62

Table 2 illustrates the effect of continued lack of sunshine on the water, wind and air conditions being similar.

TABLE 2.—Water temperature and continued cloudiness at Barnstable

Date	Sky	Temperature		Wind
		Air	Water	
1925		° F.	° F.	
Sept. 14	Cloudy	72	71.5	SW. 1.
15	do.	65	69	NE. 2.
16	do.	63	63	NE. 2.
17	do.	59	59.5	NE. 4.

The effect of continued clear skies, air and wind remaining fairly constant, is illustrated in Table 3.

TABLE 3.—Water temperature and sunshine at Barnstable

Date	Sky	Temperature		Wind
		Air	Water	
1925		° F.	° F.	
Aug. 2	Clear	73	65	SW. 3.
3	do.	74.5	68	N. 3.
4	Hazy	78	68	Calm.
5	Clear	76	69	SSW. 1.
8	do.	75	70	N. 1.

WIND

Wind is the most active agent in changing surface temperatures. On July 22, 1925, after the wind had blown offshore for 12 hours with a force increasing to 9 on the Beaufort scale, the water temperature fell from 72° to 60° and remained low through July 27. At Craigville, on the south shore, it rose 4° from 74° to 78° during this same period of high onshore winds. This change was the greatest noted on the south shore. During the period August 21, 22, and 23, 1925, the water temperature at Barnstable fell from 70.1° with the wind blowing from the northeast, force 1, Beaufort, to 67° when the wind changed to north, and rose again to 69° when the wind shifted to south, force 4. On these days the sky was clear and the air temperature uniform. The water temperature at Craigville when the wind was north, force 6 (a high offshore wind), fell 1°.

From the 15th of August, 1926, until records ceased to be kept, the prevailing wind direction was northeast and the air temperature low. In spite of clear skies, the water temperature at Barnstable under such conditions fell:

Aug. 15	74
16	73
17	68
18	65
20	62
22	60.8

Nor did it again rise above 66° except in the late afternoon.

The data for both years show that the highest water temperatures are recorded when wind of low velocity is blowing from the south or west.

AIR AND WATER TEMPERATURES

The graphs of air and water temperatures for the two summers show clearly the general relationship between these two (see fig. 2). The water curve does not coincide

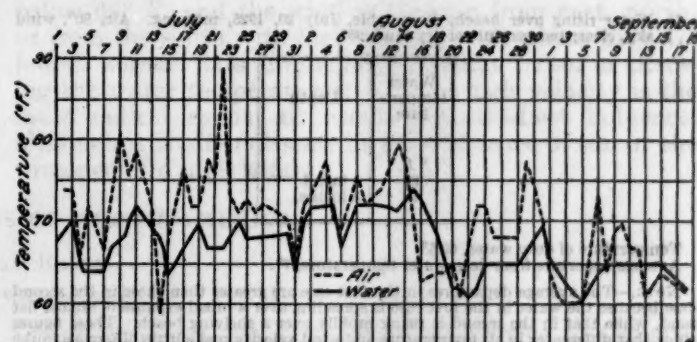


FIG. 2.—Air and water temperatures at high tide, 1926

with the air curve, but follows it with a slight lag and less amplitude. That is, when the air temperature rises, the rise in the water temperature curve is not so prominent, and its peak lags about 24 hours behind that in the former. This is to be expected largely for the reason that volume for volume water has about 3,300 times the thermal capacity of air.

TABLE 4.—Delayed effect of air upon water temperature, Barnstable

Date	Sky	Temperature		Time
		Air	Water	
1925		°F.	°F.	
July 22	Clear	80	67	10 a. m.
23	do.	73	68.5	10:30 a. m.
24	Rain	71	70	11 a. m.
25	Clear	73	68	12 m.
Aug. 13	Partly cloudy	80	71.5	4 p. m.
14	do.	78	73	Do.
15	Clear	69	74	5 p. m.
16	Rain	63	73	6 p. m.
18	Cloudy	64	68	9 p. m.

It is seen from the above data, then, that although wind can make the greatest change in the shortest time, the sun is the most important factor in controlling water temperature and that air and water coincide in general trend.

THE SHALLOW WATER OF THE NORTH SHORE

Tidal stage.—There is no shallow water at high tide either in Barnstable Harbor or at Sandy Neck, the observational points on the north side of the cape (i. e.,

when the tide is full the water is 5 to 6 feet deep at a distance of 10 feet from the shore). From low to half tide, however, shallow water rises over flats which, if the sun is shining, modify its temperature. Indeed sunned flats are the all-important factor in influencing water temperatures where the depth of the water is less than 2 feet; wind and air are relatively unimportant. The following data show the temperature changes in water rising over sunned flats (water 0 to 2 feet deep):

TABLE 5.—Temperature changes in rising water

I. Water rising over flats, Sandy Neck, July 9, 1925, morning. Air, 69°; wind, NW., 2; sky, clear; temperature of dry sand, 80°.

Water temperature	Depth
° F.	
81	1-2 inches, sunned pool.
80	6 inches.
79	6 inches, farther from shore.
73	18 inches.

Temperature of deep water, 66°.

Average departure from deep water, 12.2°.

II. Water rising over beach, Barnstable, July 20, 1925, morning. Air, 80°; wind S., 1; sky, clear; temperature of dry sand, 95°.

Water temperature	Depth
° F.	
80	1 inch.
73	8 inches.

Temperature of deep water, 69.5°.

Average departure from deep-water temperature, 7°.

NOTE.—The average departures in the first case are greater than those in the second case because the water in the first case is spreading over a broad expanse of almost flat sand, while that in the second is rising rapidly over a shelving beach. These figures show that differences in air temperature and wind velocity make little difference in the temperature of shallow water if the sun is shining.

III. Water rising over beach, Barnstable, July 23, 1925, noon. Air, 76°; sky, clear; wind, SW., 2.

Water temperature	Depth
° F.	
73	8 inches.
77.1	14 inches.

Temperature of deep water, 63°.

Average departure from deep-water temperature, 9-10°.

¹ The temperature of the deep water is lower than usual owing to the high offshore wind velocity of July 22. This difference in deep-water temperature, however, seems to make no difference in the temperature of the shallow water.

THE SHALLOW WATER OF THE SOUTH SHORE

Observations made during both summers show the average shallow-water temperature at West Harwich and Wianno to be 77.1°. The average deep-water temperature at Craigville is between 74° and 75°.

Harwich and Wianno water is warmer than Barnstable water for three reasons:

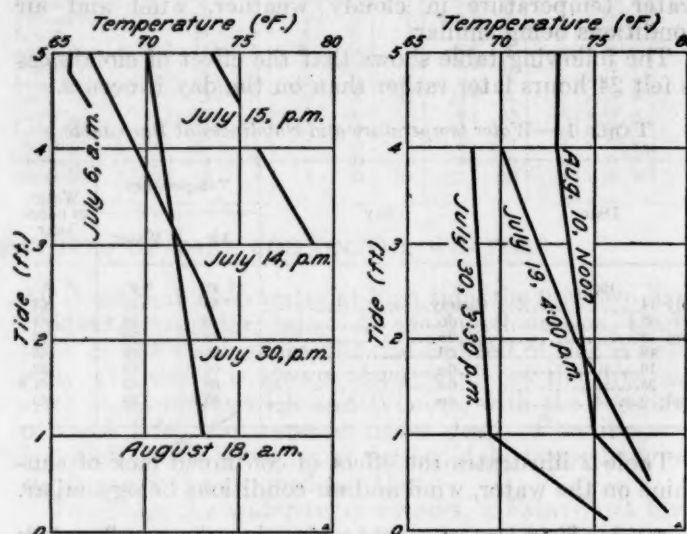
1. The general body of water south of Cape Cod is warmer than that north of the cape.
2. The water at both places is always shallow, so that the sun's rays penetrate it.
3. Harwich water rises over a broad expanse of sunned flats.

THE DEEPER WATER ALONG THE NORTH SHORE AT BARNSTABLE AND AT SANDY NECK

Tidal stage.—High-tide temperatures only will be considered here. Again, the question of sunned flats seems

to be the all-important one, as the following comparisons show.

Sun and high-tide temperatures.—That the sun has immediate effect upon water temperatures is shown by the following figures. The average temperature on clear days is 67.4°; the average for cloudy days is 65.9°; a difference of 1.5°. The effect of sunshine upon water



FIGS. 3 AND 4.—Left, falling temperature with rising tide; right, difference in temperature between deep and shallow water at the same time at high tide

24 hours later is even more marked; 68.8° is the average water temperature 24 hours after a clear day; 66.2°, 24 hours after a cloudy day, a difference of 2.6°.

The diurnal warming of sunned flats is shown by a comparison of clear-day morning and afternoon high-tide temperatures of July and August. Twenty-seven observations in the forenoon show an average of 67.4°, and an equal number in the afternoon (after 2 p. m.) show an average in the afternoon of 70.4°, a gain in the afternoon of 3°.

Falling temperature with rising tide.—The fact that the water temperature falls with rising tide shows (1) the effect of sunned flats in warming shallow water, which ceases as the water deepens, and (2) the thinness of any surface layer warmed appreciably by the sun, for, owing to the turbulence in the rising water, this thin layer soon becomes absorbed; that is, where there are no flats the temperature falls somewhat with rising tide because of this turbulence, but where the effect of flats is added the fall is greater (see fig. 3). Figure 4 shows the difference between deep and shallow water at the same time at high tide.

Wind and high-tide temperature.—The following statement shows the general relationship between wind and water:

Wind direction	Average temperature	Remarks
	° F.	
South, west, southwest.....	68.4	Weather usually fair.
Northwest, north.....	67.5	Weather usually fair but cold.
Northeast, east, southeast.....	66.1	Weather usually stormy.

The highest water temperatures occur with south or southwest winds of low velocity (temperatures over 70°). An offshore wind of high velocity, even though it be south, may lower the temperature as much as 12° in an equal number of hours.

In general it may be said that wind and air temperature go hand in hand and affect water temperature 12 to 24 hours after they themselves are felt; that is, on the first day of a cold wind the water remains warm, while on the second day it grows cooler.

THE DEEPER WATER ALONG THE SOUTH SHORE AT CRAIGVILLE

The lack of sunned flats, the constant deep water within 3 to 4 feet of the shore, and the absence of marked tidal rise and fall at Craigville all combine to keep the water temperature remarkably even at 74°-75°.

TABLE 6.—Temperature readings at Craigville

Date and time	Temperature		Suggested cause of deviation from 74°-75° F.
	Air	Water	
	° F.	° F.	
July 24, 1925, p. m.	79	78	High on shore wind of July 22.
28, 1926, a. m.	70	76	
Aug. 1, 1925, a. m.	78	75	Continued high air temperature.
2, 1925, a. m.	72	73	
15, 1926, p. m.	79	78	
18, 1926, a. m.	74	74	Rain for 3 days; lowered temperature.
23, 1925, a. m.	72	73	North wind for 2 days.
Sept. 11, 1926, a. m.	68	68	Persistent northeast wind and low air temperature.
18, 1925, a. m.	61	69	Rain and northeast wind for 3 days.

NOTE.—The afternoon temperatures seem to run slightly higher than the morning temperatures. This fact is doubtless due to the heating of the water by the sun, the higher afternoon air temperature, and the onshore sea breeze which blows the heated surface water toward the shore.

THE CLIMATIC REGIONS OF NORTH AMERICA

By W. VAN ROYEN

[Clark University, Worcester, Mass.]

The accompanying map is the result of an attempt to apply the principles used and explained by Köppen in "Petermanns Mitteilungen," 1918, (1) and later in "Die Klimate der Erde" (1923), (2) to the data found in the publications of the United States Weather Bureau and the Canadian Meteorological Service.

The map, given in "Petermanns Mitteilungen" and reprinted in black in "Die Klimate der Erde," is of too small a size to show details. Furthermore, the projection used for it distorts the features of North America too seriously to give a clear idea of the distribution of the different climatic zones over this continent.

The study had to be restricted to eastern North America north of the Rio Grande; the data available for Mexico were not sufficient to make a better approximation to a true representation of the conditions than is found on Köppen's map. Also, the number of stations with long records in the area between the Rocky Mountains and the Sierra Nevada and the Cascade Range is inadequate, especially in connection with the great topographical complexity of this region. An attempt to work out Köppen's principles for this part would necessarily have to be supplemented by observations of the vegetation in the field to fill out the gaps between the stations.

This has been done by R. J. Russell for the State of California in his "Climates of California." (3)

The above mentioned studies of Köppen,¹ and some of his publications in the Meteorologische Zeitschrift, (4, 5) have served as basis for this study.

I have used also Bulletin W of the United States Weather Bureau, the Monthly Records of Meteorological

TABLE 7.—Comparison of Craigville and Barnstable air and water temperatures

Date	Craigville				Barnstable			
	Time	Wind	Air	Water	Time	Wind	Air	Water
			° F.	° F.			° F.	° F.
1925								
July 11	5 p. m.	SW. 1	76	74	12 m.	S. 1	81	69
23	4 p. m.	SW. 5	78	78	4 p. m.	SW. 5	79	63
Aug. 1	11 a. m.	S. 1	78	75	3 p. m.	S. 5	78	67
2	10:30 a. m.	SW. 3	73	73	11 a. m.	SW. 3	72	65
23	3 p. m.	S. 4	73	73	11 a. m.	S. 1	72	69
Sept. 18	12 m.	SE. 3	61	69	12 m.	SE. 3	63	63
Average				73.6				66
Average difference				7.6				

To summarize conditions briefly, it may be said that (1) the highest water temperatures at Barnstable occur in the afternoon, on sunny days, when the air temperature is above 70° F. and a gentle wind is blowing from the south or west; and conversely, the lowest water temperatures come in the morning, on either sunny or cloudy days (preferably the latter), when the air temperature is below 65° F. and the wind is blowing from east, north, or from the south with high velocity; (2) where they are found, sunned flats are the all-important factor in affecting the water temperatures; wind of high velocity is the most radical agent; air exerts the steadiest influence, although it is often obscured by the absence of sun or the presence of a high wind.

Observations of the Meteorological Service of Canada, "The temperature and precipitation of Alberta, Saskatchewan, and Manitoba," by A. J. Connor, (6) and Hann's "Handbuch der Klimatologie." (7)

To determine the division lines on the map, more than 300 stations with long records have been used. It was necessary, moreover, to compare the data of many other stations in order to ascertain that some of the values were not due to local conditions and that they increased or decreased regularly to the one or the other side. The use of stations with shorter records than 10 years has been avoided as much as possible.

As Köppen states, climatology has to work with quantitative magnitudes. But those magnitudes in themselves do not have a practical value, and therefore a system of classification built on limits chosen entirely arbitrarily would likewise have no practical value. So we have to look for a parallelism between certain numerical facts or a certain combination of those facts and the phenomena of the organic or inorganic realm of nature. We can not expect more than a parallelism; it is impossible to express life in an exact mathematical formula.

Köppen considers the vegetation as the best object with a practical value for furnishing those limits.

The most important factors to be considered in this connection are:

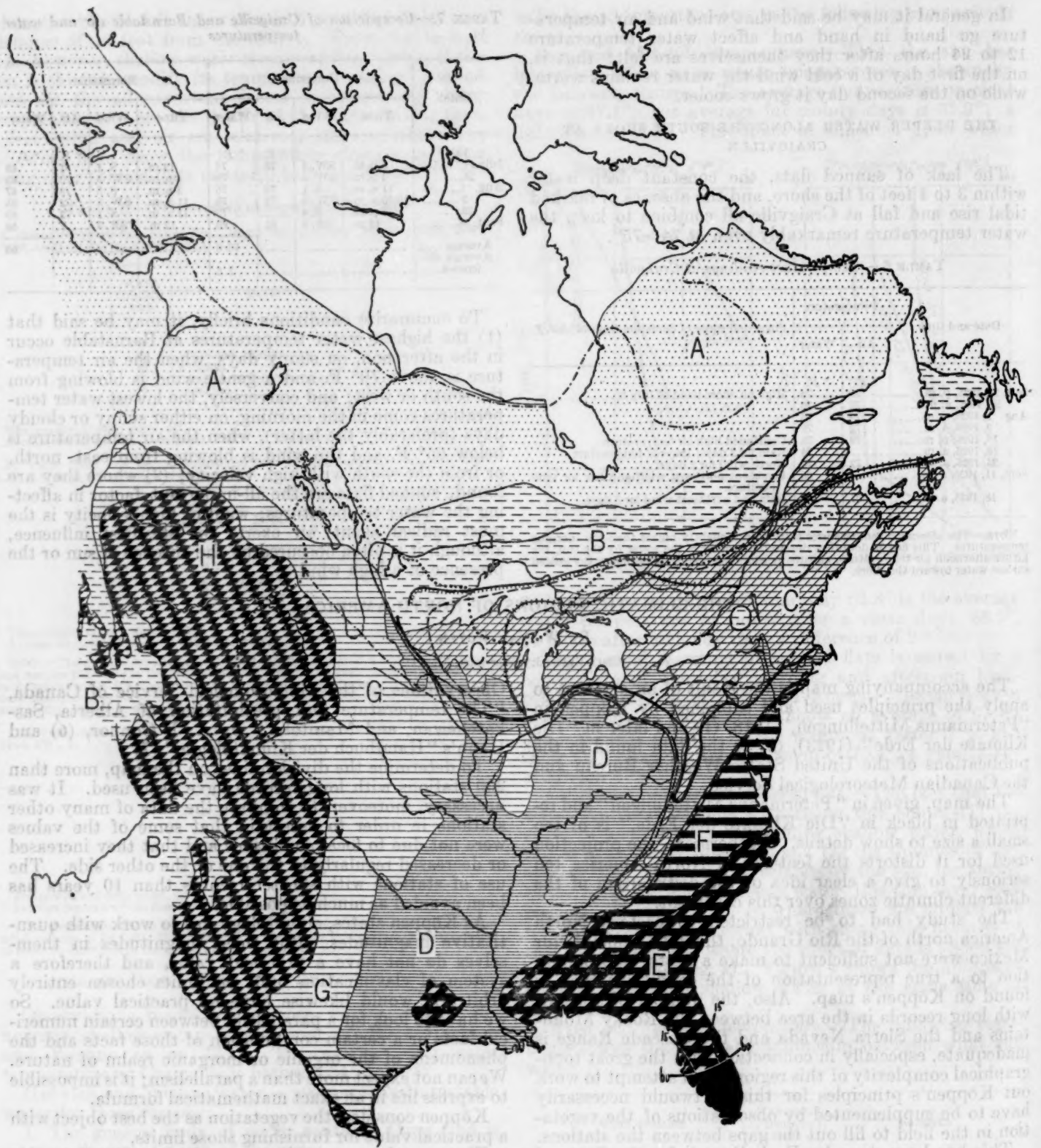
(a) Whether rest periods, or at least periods of very restricted organic activity, are present.

(b) The duration of the period favorable for organic life.

(c) The conditions during that period.

These factors were kept in view constantly by Köppen in determining his criteria.

¹Vide: Preston E. James, Köppen's Classification of Climates: A Review, MONTHLY WEATHER REVIEW, February, 1922, 50: 69-72.



Northern and southern limit of:

- *Pinus strobus*
- *Tsuga canadensis*
- *Populus balsamifera*
- Southern limit of:
- *Abies balsamea*

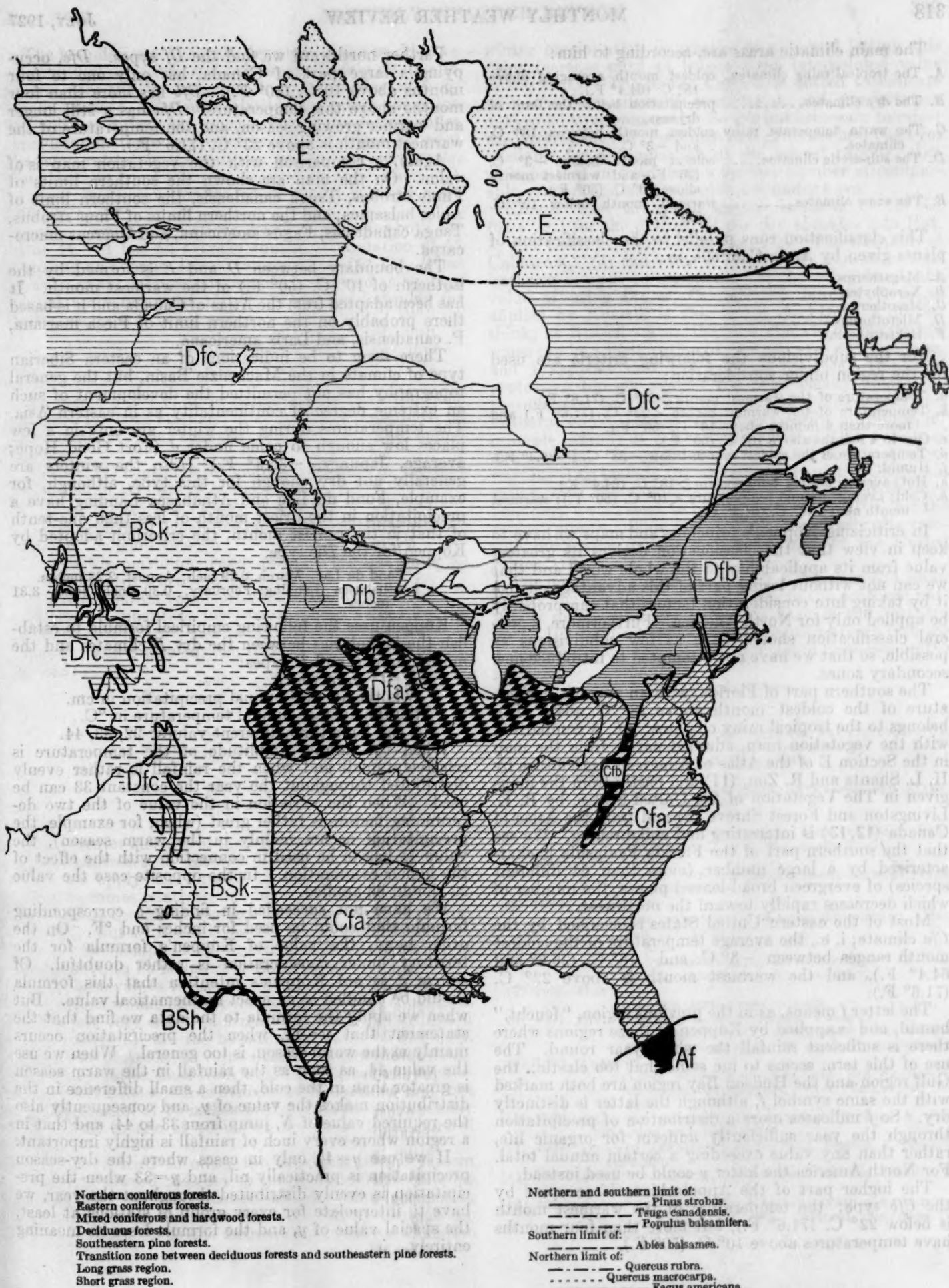
Northern limit of:

- *Quercus rubra*
- *Quercus macrocarpa*
- *Fagus americana*

60—60 Number of evergreen broad leaved trees south of line

- A. Tropical rainy climates.
- B. Dry climates.
- C. Warm temperate rainy climates.
- D. Subarctic climates.
- E. Snow climates.
- a. Temperature of warmest month $>72^{\circ}\text{F.}$

- b. Temperature of warmest month $<72^{\circ}\text{F.}$, more than four months $>50^{\circ}\text{F.}$
- c. One to four months $>50^{\circ}\text{F.}$, coldest month $>-36^{\circ}\text{F.}$
- f. Enough rain or snow in all months.
- g. Steppe climate.
- k. Cold; some months $<50^{\circ}\text{F.}$
- h. Hot; coldest month $>50^{\circ}\text{F.}$



The main climatic areas are, according to him:

- A. The tropical rainy climates—coldest month averaging above 18° C. (64.4° F.).
- B. The dry climates—precipitation below the limit of dryness.
- C. The warm temperate rainy climates—coldest month between 18° C. and -3° C.
- D. The sub-arctic climates—coldest month below -3° C. (26° F.) and warmest month above 10° C. (50° F.).
- E. The snow climates—warmest month below 10° C. (50° F.).

This classification runs parallel to the classification of plants given by A. de Candolle, in:

- A. Megatherms.
- B. Xerophytes.
- C. Mesotherms.
- D. Microtherms.
- E. Hekistotherms.

For the subdivisions the following criteria are used for the region under consideration:

- a. Temperature of the warmest month >22° C. (71.6° F.).
- b. Temperature of the warmest month <22° C. (71.6° F.) and more than 4 months above 10° C. (50° F.).
- c. One to 4 months above 10° C. (50° F.).
- d. Temperature of the coldest month below -38° C. (-36.4° F.).
- f. Humid.
- h. Hot; average annual temperature >18° C. (64.4° F.).
- k. Cold; average annual temperature <10° C. (50° F.); warmest month above 18° C. (64.4° F.).

In criticizing Köppen's principles and maps we have to keep in view that the classification derives its greatest value from its applicability to the whole world and that we can not without losing part of this advantage change it by taking into consideration factors that can probably be applied only for North America. Furthermore, a general classification should have as few subdivisions as possible, so that we have not attempted to introduce new secondary zones.

The southern part of Florida, with an average temperature of the coldest month above 18° C. (64.4° F.), belongs to the tropical rainy climates: *Af*. A comparison with the vegetation map, adapted partly from the map in the Section E of the Atlas of American Agriculture by H. L. Shantz and R. Zon, (11) and partly from the maps given in The Vegetation of the United States, by B. E. Livingston and Forest Shreve (8) and from the Atlas of Canada (12, 13) is interesting and enlightening. We see that the southern part of the Florida Peninsula is characterized by a large number (more than 64 different species) of evergreen broad-leaved plants, the number of which decreases rapidly toward the northwest.

Most of the eastern United States is occupied by the *Cfa* climate; i. e., the average temperature of the coldest month ranges between -3° C. and 18° C. (26.6° and 64.4° F.), and the warmest month is above 22° C. (71.6° F.).

The letter *f* means, as in the previous region, "feucht," humid, and is applied by Köppen to those regions where there is sufficient rainfall the whole year round. The use of this term seems to me somewhat too elastic; the Gulf region and the Hudson Bay region are both marked with the same symbol *f*, although the latter is distinctly dry. So *f* indicates more a distribution of precipitation through the year sufficiently uniform for organic life, rather than any value exceeding a certain annual total. For North America the letter *y* could be used instead.

The higher part of the Appalachians is occupied by the *Cfb* type; the temperature of the warmest month is below 22° C. (71.6° F.), but more than four months have temperatures above 10° C. (50° F.).

Farther northward we find the *Df* types. *Dfc*, occupying a large part of Canada, has only one to four months above 10° C. (50° F.). *Dfb* has more than four months above this temperature. *Dfa* has a still longer and warmer growing season, and the temperature of the warmest month is above 22° C. (71.6° F.).

Again, a comparison with the vegetation map is of value. On the map are shown the southern limits of *Pinus strobus*, *Tsuga canadensis*, the southern limit of *Abies balsamea*, and the northern limits of *Pinus strobus*, *Tsuga canadensis*, *Fagus americana*, and *Quercus macrocarpa*.

The boundary between *D* and *E* is formed by the isotherm of 10° C. (50° F.) of the warmest month. It has been adapted from the Atlas of Canada and it is based there probably on the northern limit of *Picea mariana*, *P. canadensis*, and *Larix americana*.

There seem to be indications of an eastern Siberian type of climate in the Mackenzie Basin, but the general topography has not permitted the development of such an extreme degree of continentality as in eastern Asia. The temperatures during the winter are only in a few places low enough to come under *d* (Fort Good Hope; average, January, -36.3° F.). Also the winters are generally not dry enough for this type, although, for example, Fond du Lac and Athabasca Landing have a precipitation in the driest month of less than one-tenth of that in the rainiest month, the criterium adopted by Köppen for the *Dw* type.

Fond du Lac: March, 0.19 inch; August, 2.23 inches.
Athabasca Landing: February, 0.30 inch; June, 3.31 inches.

Köppen uses the following empirical formula to establish the boundaries between the dry *B* climates and the more humid *C* and *D* types:

$$N = t + y, \text{ in which}$$

N is the average annual precipitation in cm.

t is the average annual temperature in °C.

y can have three different values: 22, 33, 44.

When the annual amplitude of the temperature is relatively small and when the rainfall is rather evenly distributed throughout the year the constant 33 can be used. When the variation in the value of the two determining factors is rather great (when, for example, the precipitation occurs mainly in the warm season), the value 44 has to be used in connection with the effect of the higher evaporation. In the opposite case the value 22 should be applied.

We have not succeeded in finding a corresponding formula that could be used for inches and °F. On the other hand, the value of Köppen's formula for the territory under consideration is rather doubtful. Of course it is not Köppen's intention that this formula should be handled as an exact mathematical value. But when we apply the formula to the data we find that the statement that *y*=44, when the precipitation occurs mainly in the warm season, is too general. When we use the value 44, as soon as the rainfall in the warm season is greater than in the cold, then a small difference in the distribution makes the value of *y*, and consequently also the required value of *N*, jump from 33 to 44, and that in a region where every inch of rainfall is highly important.

If we use *y*=44 only in cases where the dry-season precipitation is practically nil, and *y*=33 when the precipitation is evenly distributed throughout the year, we have to interpolate for every group of stations at least, the special value of *y*, and the formula loses its meaning entirely.

The boundaries of the main dry areas of the world have a latitudinal direction, and only in the Baraba Steppe in Siberia does the dry region push as far northward as in North America. For such a latitudinal extent the value of t will not differ very much. But in the region under consideration there is a considerable difference between the temperatures in the southern and the northern parts. This leads to complications, because an application of a necessary correction for the whole region is much more difficult.

Let us assume two stations A and B ; y has for both the value 44. A has an average annual precipitation of 45 c. m. and an average annual temperature of 2°C . B has an average annual precipitation of 58 c. m. and an average annual temperature of 15°C . Then the formulae for both stations will be:

$$A: 45 < 2 + 44.$$

$$B: 58 < 15 + 44.$$

An increase of 1 c. m. in rainfall would have the same influence for both stations; it would bring them both on the boundary line between the dry and the humid regions.

Trabert (9) considers the following formula as the best expression of the rate of evaporation:

$$\sqrt{v} = c(l + \alpha t) \sqrt{W} (E = e), \text{ in which}$$

c is a constant depending on the barometric pressure.

w is the wind velocity.

E is the maximum vapor pressure for the temperature of the evaporating surface.

e is the actual vapor pressure in the air above.

When we substitute the corresponding values for the temperatures 5° , 10° , and 15°C ., considering c and w as constant, and e also for the region under consideration, we find:

$$V_5 = c \times \frac{278}{273} \times \sqrt{w} (6.5 - e).$$

$$V_{10} = c \times \frac{283}{273} \times \sqrt{w} (9.2 - e).$$

$$V_{15} = c \times \frac{288}{273} \times \sqrt{w} (12.8 - e).$$

The greater increase of the value of V , when t increases, is not expressed in Köppen's formula. The result is, when we apply the formula to the data, that the dry region becomes relatively too broad in the northern part. Stations in the forest region of Canada with a low precipitation but with a still lower average annual temperature, as, for example, Fort McMurray and Fort Vermillion, would have to be included in the B area.

The best values to use in combination with precipitation values would be evaporation data. But these data are as yet very scant, and maps, as used by Livingston and Shreve (8), are too hypothetical to be of any help. The Atlas of American Agriculture (10) gives some available evaporation data from which a decrease in evaporation toward the north is evident, and mentions also that a precipitation of 20 inches in the Dakotas is practically equivalent to one of 40 inches in the southern part of Texas.

We have tried to offset the deviation of the eastern boundary toward the east by interpolating the value for y according to the relative amount of precipitation occurring during the summer season and by using in the northern part 44 as the extreme value (i. e., when the

winter precipitation is practically nil), and letting this value increase until 44 becomes the interpolated value in the south. The line in Canada is dotted to indicate its probable position if evaporation and precipitation data could have been used. So it is not necessary to reject the formula entirely, inasmuch as it gives the best basis yet available for a comparison of the largest regions. Let us hope that in the future a greater number of comparable evaporation data will give a sounder basis.

Köppen uses the mean annual isotherm of 18°C . (64.4°F .) for the division of the dry climates into Hot, h , and Cold, k . As Russell states in "The Climates of California," (3) the value of using such a mean annual isotherm is open to question. On the other hand, the value of using the 0°C . (32°F .) January isotherm applied by Russell, is also rather doubtful. I do not think, as Russell states, that the climate of Pleistocene times can be a justification for the choice of this isotherm, and I suppose that the average American thinks of protecting himself against the cold usually before the thermometer reaches the 32° average. The use of this isotherm would also, entirely unnecessarily, introduce, for example, islands of BWh climate in the BWk region of Transcaspia. In addition to that, it does not seem warranted to include the southern part of the California valley with the Colorado desert. A more satisfactory boundary would seem to be the isotherm of 50°F . for the coldest month. This line includes practically the creosote bush area on the vegetation map of the United States. (10)

The mountain areas, classified by Köppen as Dfb , show mostly the Dfc type, and, of course, in the southern part this is somewhat more important than in the northern part. The highest crests of the mountains reach into the E zone, but these regions are too small to be shown on the map.

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TEN YEARS OF EVAPORATION IN THE SOUTHWEST

By CHARLES E. LINNEY

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Theories as to the rate of evaporation and the elements that cause or promote it have been multiplied through the years. Beginning as early as 1670, British scientists were formulating theories of evaporation, and in 1687 Edwin Halley gave a paper before the Royal Society wherein he estimated the quantity of vapor (evaporation) raised out of the sea by the heat of the sun. And calculations were given as to the probable amount of evaporation from the Mediterranean Sea in a summer day. The accelerating influence of wind on evaporation was observed. Others followed on down to John Dalton, who may be called "the father of the science."

As early as 1793 Dalton published in London an essay in which he set forth the process and circumstances promoting evaporation—heat, dry air, and decreasing pressure of the atmosphere upon the evaporating surface are emphasized. In his experiments the rate of evaporation from water pretty well exposed to the sun and wind never exceeded 0.2 inch daily. In 1801 Dalton published his new theory of the constitution of mixed aeriform fluids and particularly of the atmosphere. Again in 1802 Dalton, in his experimental essays says:

The objects are:

1. To determine the effect of temperature upon the rate of evaporation.
2. To determine the relative evaporation of different fluids.
3. To find a rule for ascertaining the quantity and effect of water vapor previously in the air.
4. From these and other facts to obtain a true theory of evaporation.

Out of this came the Dalton formula.

And down through the years the problems of evaporation have continued to develop many items and articles of interest. The experiments of Prof. F. H. Bigelow¹ at Reno, Nev., and at Salton Sea, Calif., tended to show that pans for evaporation that were buried in the ground would absorb too much heat from the soil and therefore show a greater evaporation than that which was obtained from simultaneous observations from pans floated upon the surface of water near by. This occurred in observations at Hemiston, Oreg., and Granite Reef, Ariz. On the other hand, Professor Carpenter, in experiments at Fort Collins, Colo., apparently met with the reverse condition and found both temperature and evaporation less from ground pans than from those which were obtained in near-by lakes or reservoirs and increased his figures accordingly. A like condition was obtained at Croton Reservoir, near New York City, and the figures from early observations at the New Mexico Agricultural College appear to conform to this and to confirm it when compared with data from Lake Avalon and Fort Bliss.

In theory, it would seem as if records which were obtained from pans floated upon the waters of a reservoir should show more nearly the correct evaporation than those which were obtained from pans buried in the ground near by or from those placed above the ground near by. Despite theory and the conclusions of Professor Bigelow, the standard finally adopted by the Weather Bureau consists of a 4-foot galvanized iron pan, 10 inches in depth, exposed on an open platform of spaced 2 by 4 timbers, raised slightly above the ground for circulation of air all round the pan, a still well and hook gauge, and, near by, a cotton region shelter with maxi-

mum and minimum thermometers, rain gauge and anemometer, the latter exposed beside and just above the tank. Just why this pattern was adopted I do not know, but it affords a uniform equipment, and the records should be in fair accord. I hope, therefore, that the following observations will prove interesting and that in time they will aid in securing a suitable formula to approximate evaporation at any station when the elements which enter into evaporation are known—insolation, temperature, precipitation, humidity, vapor pressure, wind movement, and probably barometric pressure, although I believe that too much stress has been placed upon barometric pressure by some of the investigators who conclude that evaporation is greater in the high altitudes because of the dryness and the reduced air pressure. Thus Hann says (*Climatology*, pp. 290-291):

Under similar conditions of relative humidity, temperature, and wind velocity, evaporation is much greater on mountains than at lower levels because of the diminished pressure aloft. Everything dries much more rapidly at great altitudes. * * * The relative humidity alone is, therefore, no sufficient criterion for the evaporating powers of a mountain climate, the diminished pressure making it possible for the water vapor which has been formed to be distributed much more rapidly through the air, and hence evaporation is accelerated.

However, those of us who live in the higher regions of the Southwest know from daily experience of the increased precipitation and humidity, the cooler air, and the comparatively quiet wind movement that obtains, and the records thus far show evaporation considerably less than that obtained at near-by lower stations.

Investigators have also lamented the lack of uniformity in evaporation observations, the lack of uniform equipment, and the lack of a common interest, and a definite goal. Thus Hann says: "It is, unfortunately, a difficult matter to make observations of evaporation which shall be strictly comparable. In order to carry out such measurements it would be advisable to use evaporimeters which are precisely alike and to expose them in exactly the same way. But," he concludes, "even the amount of evaporation from a perfectly free water surface under sunshine is uncertain, because this depends also upon the depth, extent, and temperature of the body of water, and upon many other local causes."

It will thus be apparent, as we proceed, why so great variation appears in the comparatively limited area under consideration.

Weather Bureau evaporation stations began to operate in 1916, so that we have approximately 10 years of fairly complete records for consideration and comparison from the dozen stations in Texas, New Mexico, and Arizona.

The station at Santa Fe was placed in operation in May, 1916, and has been in continuous operation since. I mention this because many of the stations in the North and East do not undertake winter readings. The results show an average annual evaporation of 64.707 inches. The year 1917, which was the driest during the period, gave the largest evaporation, 75.815 inches, while 1919, the wettest, gave the lowest, 56.397 inches. The year 1917 was much warmer and drier and more windy than usual, while, on the other hand, the year 1919 was cool, quiet, and wet. The former represents a year with maximum evaporation and the latter a year with minimum.

The march through the year begins with a minimum in December, which averages 1.393 inches, and increases

¹ MONTHLY WEATHER REVIEW: July, 1907, 35:311-316; February, 1908, 36:24-39; Annual Summary, 1908; 36:437-445; February, 1910, 38:307-316; July, 1910, 38:1133-1135.

slowly in January, February, and March, while more or less ice obstructs the pan, but jumps (almost doubles) in April, with the increasing warmth and wind, going up rapidly until it reaches the maximum of the year in June, and going steadily downward thereafter to the minimum in December. The greatest monthly amount measured during the period was 11.989 inches in June, 1924, although almost as large an amount was measured in June, 1916, and June, 1917. The greatest heat of the year occurs in July, but it is also the wettest month of the year and much less windy than June; hence the greater evaporation in the latter month.

An interesting side light is cast upon the evaporation of the station and of the Southwest by a comparison of the actual results with the theoretical values given by Prof. Thomas Russell in the MONTHLY WEATHER REVIEW in 1888 (p. 239). He places the figure for Santa Fe at 79.8 inches, apparently having given too high value to the effect of altitude and, in theory, the drier atmosphere due to this factor.

TABLE 1.—Estimated evaporation
[Inches]

Station	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Fort Davis.....	5.4	5.7	6.7	8.5	11.0	12.0	11.4	9.0	5.9	5.2	5.7	4.9	96.4
Fort Stanton.....	3.9	3.9	5.2	7.3	9.5	10.9	9.4	11.6	3.9	4.0	3.6	3.8	76.0
El Paso.....	4.0	3.9	6.0	8.4	10.7	13.6	9.4	7.7	5.5	5.2	4.6	2.9	82.0
Santa Fe.....	3.0	3.4	4.2	6.5	8.8	12.9	9.2	9.8	6.6	6.7	5.7	2.7	79.8
Fort Apache.....	2.6	3.0	3.6	6.2	9.4	9.1	7.1	6.7	5.3	5.2	4.1	2.6	65.5
Fort Grant.....	5.2	4.8	6.4	9.2	10.2	13.8	12.4	10.5	9.0	7.9	7.2	4.6	101.2
Prescott.....	1.4	2.8	3.6	5.4	6.2	8.1	6.6	6.8	4.7	4.9	3.6	2.2	56.0
Yuma.....	4.4	5.2	6.6	9.6	9.6	12.6	11.0	10.2	8.2	8.2	5.5	4.6	95.7

I will content myself in this paper with a rather close survey of the data from the agricultural college and a more general and brief survey of the others in the group.

The agricultural college was made a standard station in September, 1918, hence has an eight-year record, and this is complete for temperature, precipitation, wind velocity, humidity, vapor pressure, dew point, and the resulting evaporation. I have not included the wet and dry readings nor the results to be obtained from them in the summary table. As at Santa Fe, so also at this station the lowest of the year occurs in December and the highest in June, with, however, a more uniform ascent and decline, since the season of ice is much shorter and accordingly much less troublesome. The annual average is 88.254 inches. The average monthly minimum is 2.520 inches in December and the average monthly maximum 11.906 in June, when clear skies, heat, dryness, and wind combine to give the largest evaporation. The maximum yearly record was 98.014 inches in 1922 and the minimum 75.566 in 1926, the latter a quiet, cool, wet year.

Within the State of New Mexico the greatest evaporation is apparently at the Elephant Butte Dam station. The pan here is placed on the bank of the lake about 100 feet above the water and is very freely exposed to the winds. The annual average is 100.617 inches, with a maximum of 109.692 inches in 1917 and a minimum of 84.247 inches in 1926, the former a dry, hot, windy year and the latter a wet, cool, and comparatively quiet one.

One of the interesting comparisons made possible by the dry years 1924-25 and the consequent emptying of Lake Avalon is that of the floating pan which for several years had been exposed in the spillway basin of the lake, but, because of the dryness and lack of water, was removed to the land adjacent. The annual average, as shown by the floating pan, is about 75.250 inches, but

with the placing of the pan upon the land it at once jumped to 112.850 inches for the year 1925, and would probably have exceeded 100 inches for the year 1926 if the record could have been kept for the entire year. A brief record from a floating pan at Santa Fe, taken by the State engineer some years ago, showed an annual average of 59.370 inches. A similar record at Fort Bliss (from a pan on the Rio Grande) gave 85.910 inches, another at Elephant Butte gave 86.950 inches, and a sunken pan at the agricultural college gave 67.640 inches. On the other hand open pans at Carlsbad, N. Mex., and Granite Reef, Ariz., gave 107.250 and 115.180 inches, respectively.

On the plains a station at Spur, Dickens County, Tex., in a record from 1922 to 1926, inclusive, shows an annual average of 64.902 inches, with a maximum of 71.763 inches in 1922 and a minimum of 53.175 inches in 1926. The highest monthly record during the period was 10.923 inches in July, 1922, and the lowest 1.522 inches in December, 1926. The average for this station seems low, but may be accounted for by increased rainfall. However, a sunken pan station at the experiment farm near Tucumcari, N. Mex., although having records for the growing season only (April to September), seems to show a much larger average, due to the high winds of the plains country. And at this station a maximum monthly record of 12.380 inches was noted in July, 1922.

In mid-west Texas, at Hill's ranch, the annual evaporation averages 66.565 inches, with a maximum yearly amount of 80.447 inches in 1917 and a minimum yearly amount of 60.422 inches in 1926. The highest monthly record was 12.335 inches in July, 1918, and the lowest 1.838 inches in December, 1926.

A third station in Texas, Beeville, is on the coast and, while not in the Southwest proper, is interesting as showing the reduction due to increase in precipitation, for temperatures are high at the station and the wind movement is the greatest of any of the stations under consideration. This station shows an annual average of 60.683 inches, with a maximum of 67.541 inches in 1925 and a minimum of 53.652 in 1926.

In Arizona six stations have been maintained. Lee's ferry, on the north bank of the Colorado River, has but one complete year of record during the period.

The station at Roosevelt, by the side of the lake, shows an annual average of 84.004 inches; highest yearly, 94.642 inches in 1917; lowest yearly 82.421 in 1920; highest monthly, 13.720 inches in June, 1921; lowest monthly, 1.496 in December, 1926, a month with 4.70 inches precipitation.

The Mesa experiment station, in the center of the State, shows an annual average of only 77.356 inches, due, probably, to the exposure of the pan in a field of alfalfa; highest yearly 88.905 inches in 1921; lowest yearly 66.951 in 1926; highest monthly 12.822 inches in June, 1921; lowest monthly 1.792 inches in January, 1917, a month with light winds, much precipitation and cool weather.

Wilcox, in the southeast part of Arizona, shows an annual average of 91.701 inches; highest 105.545 inches in 1924; lowest 83.441 inches in 1919; highest monthly 13.943 inches in June, 1917; lowest 2.567 in January, 1917, the latter a wet, cool, and rather quiet month.

The Yuma citrus station, an exposure southwest of the city of Yuma on the bare mesa, shows an annual average of 121.608 inches; highest 135.688 inches in 1921; lowest 111.300 in 1926; highest monthly 20.363 inches in July, 1924; lowest 2.960 inches in December, 1926, a cool, quiet, and wet month. And, finally, the Yuma evaporation station on the mesa near to the city, with the pan exposed in a field of alfalfa. This shows an annual

HOURLY RAINFALL PROBABILITIES AT SAULT STE. MARIE, MICH.

By C. L. RAY

[Weather Bureau, Sault Ste. Marie, January 5, 1927]

Hourly precipitation probabilities for Lansing, Mich., prepared in 1925¹ give a fair approximation of rainfall distribution over the 24-hour period so far as the Lower Peninsula of the State is concerned. The accompanying paper has been prepared with the idea of presenting a somewhat similar arrangement, using the 22-year precipitation records of Sault Ste. Marie, Mich. This station, located at the eastern edge of the Upper Peninsula, latitude 46° 30', longitude 84° 21', is typical of that section, at least during the period considered, namely, from May to October, inclusive. During these months four regular observing stations show only slight variation as regards the number of days with 0.01 inch or more of precipitation, Escanaba averaging 68 days, Houghton 71, Marquette 77, and Sault Ste. Marie 73. The total annual rainfall for the Upper Peninsula ranges from 26 inches in western Marquette County to 34 inches in Iron County, while Sault Ste. Marie in Chippewa County has an annual total of about 31 inches, a fair average for the section.

An apportionment of the rainfall by hours as shown in Table 1 and Figures 1 and 2 reveals a maximum hourly rainfall between 2 and 3 a. m., where the six months May-October is considered as a unit. Taking the months separately, some variation from this average is to be observed. In May the maximum is found between 3 and 4 p. m.; in June and July it also falls in the p. m. period, though during the late evening hours; in August and September it occurs between 2 and 3 a. m., coinciding with the average for the six months, while in October the maximum total shifts to afternoon again, occurring during the hour ending at 6 p. m.

TABLE 1.—Total hourly amounts of precipitation (inches) May-October, for 22 years, 1905-1926, inclusive, S. Ste. Marie, Mich.

	Hours ending (a. m.) at—											
	1	2	3	4	5	6	7	8	9	10	11	12
May.....	1.95	1.50	2.04	1.92	2.11	2.55	2.46	2.25	3.11	2.71	1.74	2.12
June.....	1.92	1.54	2.02	2.39	2.31	3.54	2.50	2.11	2.91	2.20	2.29	1.84
July.....	2.12	3.05	3.00	2.54	3.06	2.27	1.81	1.38	1.09	1.41	1.36	2.20
August.....	1.65	2.75	4.73	1.88	2.91	4.40	3.50	1.94	1.94	2.26	2.19	1.54
September.....	4.08	3.19	4.75	3.80	3.21	2.25	2.62	3.95	2.14	2.52	2.98	2.17
October.....	2.50	2.77	2.61	2.82	2.64	2.45	2.43	2.34	2.07	2.56	2.52	2.39
Means.....	2.37	2.47	3.19	2.56	2.71	2.92	2.55	2.33	2.21	2.28	2.18	2.04

	Hours ending (p. m.) at—												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
May.....	1.95	2.02	2.37	3.22	1.66	2.13	1.79	2.11	1.74	1.73	1.94	1.71	50.83
June.....	2.77	2.24	2.57	2.22	3.19	2.36	2.30	1.50	1.75	2.01	4.62	2.13	57.23
July.....	1.55	1.67	2.21	3.32	2.62	3.46	1.78	3.31	2.57	3.75	2.25	2.24	58.05
August.....	1.04	1.97	3.01	2.98	1.89	2.63	4.04	3.24	1.60	2.44	2.53	1.87	60.99
September.....	3.55	2.36	2.10	1.96	1.83	1.77	2.03	1.76	1.91	2.89	2.80	3.05	65.67
October.....	1.99	1.74	2.67	2.67	3.04	3.50	2.39	2.23	2.91	3.05	3.02	1.96	61.27
Means.....	2.14	2.00	2.49	2.73	2.37	2.64	2.37	2.36	2.08	2.64	2.86	2.16	.....

In Table 2 is given the percentage of precipitation occurring during six-hour periods, from midnight to 6 a. m., 6 a. m. to noon, etc. This grouping of hours in

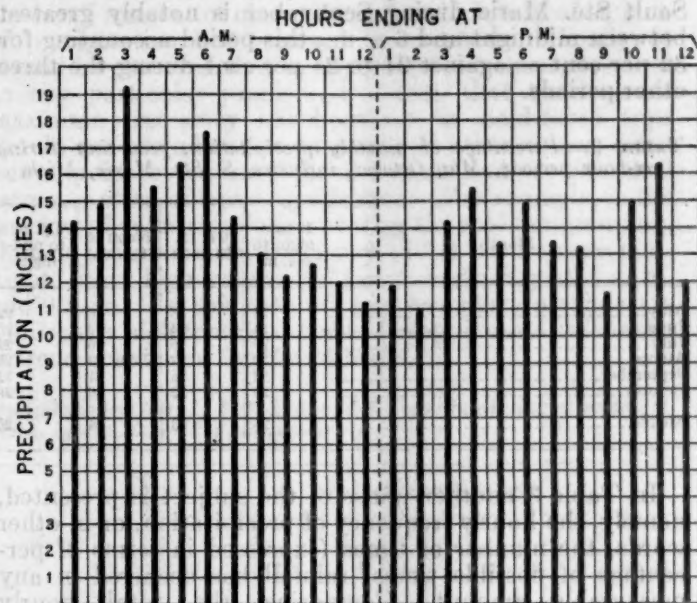


FIG. 1.—Total hourly amounts of precipitation, May to October, 1905 to 1926, inclusive, Sault Ste. Marie, Mich.

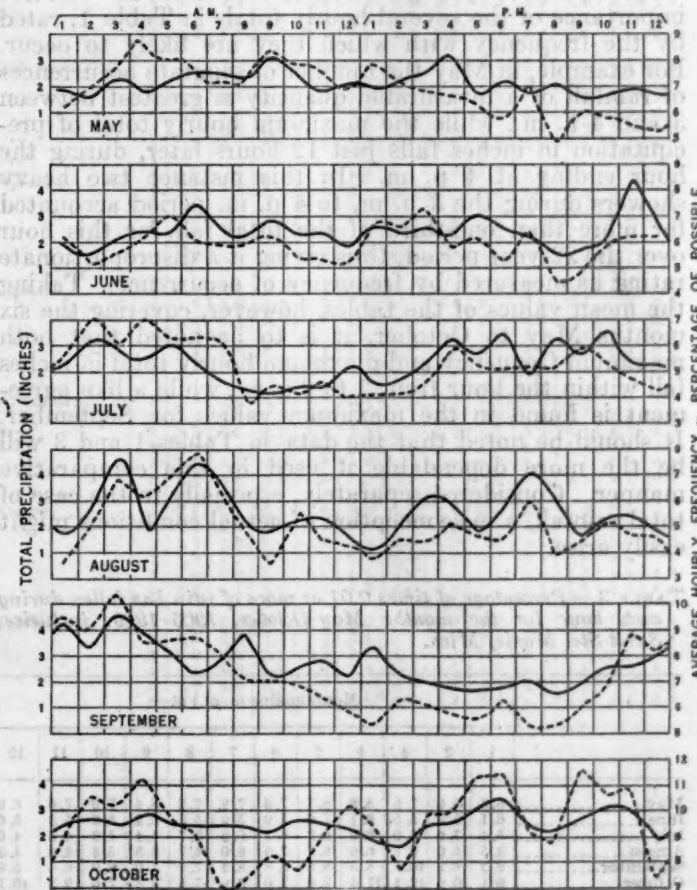


FIG. 2.—Total hourly amounts of precipitation and average hourly frequency, May to October, 1905 to 1926, inclusive, Sault Ste. Marie. Data from Table 1 (frequency equals number of times 0.01 inch or more occurred).

¹ Mo. Wea. Rev. 53: 256.

relation to rainfall frequently is of value in weighing the probabilities for different periods of the day, especially in planning for insurance of outdoor events against inclement weather. For example, the percentage of rainfall at Sault Ste. Marie during September is notably greatest between midnight and 6 a. m., this period accounting for 32 per cent as against 21 to 25 per cent during the three other periods.

TABLE 2.—Percentage of monthly precipitation, occurring during six-hour periods, May–October, inclusive, S. Ste. Marie, Mich.

Month	12 mid- night to 6 a. m.	6 a. m. to noon	Noon to 6 p. m.	6 p. m. to mid- night
May	24	28	26	22
June	24	24	27	25
July	29	16	26	29
August	30	22	22	26
September	32	25	21	22
October	26	22	26	26
Means	28	23	24	25

In Table 3 another phase of the subject is presented, namely, the hourly frequency of precipitation, or in other words, the number of times (expressed in terms of percentage of possible times) rainfall has occurred in any measurable amount. Comparing the total hourly amounts in Table 1 with the frequency values in Table 3, we are able to gauge more definitely the average intensity of precipitation per given hour and also the relative importance of the several hourly totals in Table 1, rated by the frequency with which they are likely to occur. For example, in May the number of separate occurrences of rainfall of a measurable quantity is greatest between 3 and 4 a. m., while the maximum hourly total of precipitation in inches falls just 12 hours later, during the hour ending at 4 p. m. In this instance two heavy showers during the 3 p. m. to 4 p. m. period accounted for more than one-third of the total fall for this hour over the 22-year period, thus giving it a disproportionate rating as measured by frequency of occurrence. Taking the mean values of the tables, however, covering the six months May to October, it is to be noted that both maximum frequency and maximum hourly total in inches fall within the hour from 2 to 3 a. m., while a like agreement is found in the maximum values for September. It should be noted that the data in Tables 1 and 3 will be the more dependable if used in this comparative manner. Considered separately, especially in the case of total rainfall, a misconception of actual conditions might easily arise.

TABLE 3.—Percentage of times 0.01 or more of rain has fallen during each hour for the months May–October, 1905–1926, inclusive, Sault Ste. Marie, Mich.

	Hours ending (a. m.) at—											
	1	2	3	4	5	6	7	8	9	10	11	12
May	6.3	6.0	7.6	8.8	8.1	7.9	7.2	7.2	8.4	7.3	7.6	6.9
June	6.1	8.2	5.5	6.1	7.0	5.9	5.9	5.8	6.2	5.3	5.3	5.0
July	5.4	7.0	6.0	6.9	6.3	6.3	6.2	3.7	4.4	4.3	4.5	4.0
August	3.5	5.0	6.7	6.0	6.7	7.8	6.0	4.7	3.5	5.6	4.4	4.3
September	9.2	8.9	10.5	8.5	8.5	8.8	8.2	7.1	7.0	6.9	6.4	5.9
October	9.1	10.6	10.1	11.3	9.6	9.0	6.9	7.4	8.4	7.6	9.3	10.1
Means	6.6	7.3	7.7	7.9	7.7	7.6	6.7	6.0	6.3	6.3	6.2	6.0

TABLE 3.—Percentage of times 0.01 or more of rain has fallen during each hour for the months May–October, 1905–1926, inclusive, Sault Ste. Marie, Mich.—Continued

	Hours ending (p. m.) at—											
	1	2	3	4	5	6	7	8	9	10	11	12
May	7.8	7.2	6.9	6.6	6.4	5.6	7.0	4.8	6.0	6.0	5.4	5.3
June	6.7	6.4	7.4	3.8	6.2	5.4	6.4	4.4	4.8	6.0	6.2	6.2
July	4.0	4.0	4.7	6.0	5.1	5.0	5.1	5.0	5.9	5.3	4.7	4.4
August	3.8	4.5	4.4	5.1	4.7	4.5	6.0	4.0	4.5	5.3	4.7	4.7
September	5.3	6.5	6.2	5.9	5.6	6.4	5.4	5.3	6.1	6.9	9.1	8.3
October	9.3	7.5	9.8	9.8	11.2	11.3	9.1	8.7	11.6	10.6	10.7	7.4
Means	6.2	6.0	6.6	6.5	6.5	6.4	6.5	5.4	6.5	6.4	6.8	6.0

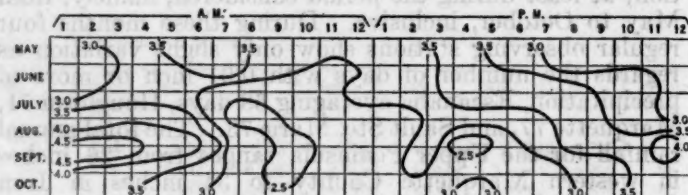


FIG. 3.—Percentage of frequency of 0.10 inch or more precipitation within three-hour period, beginning at 12 midnight, 1 a. m., 2 a. m., etc. Data for 22 years, 1905 to 1926, Sault Ste. Marie.

A more detailed and specific table of frequencies is shown in Table 4 and Figures 3, 4, 5, especially adapted to the use of those interested in planning rainfall insurance, in which the usual requirement for verification is 0.10 of an inch within the specified period. The data contained in this table are simply an elaboration of Table 3.

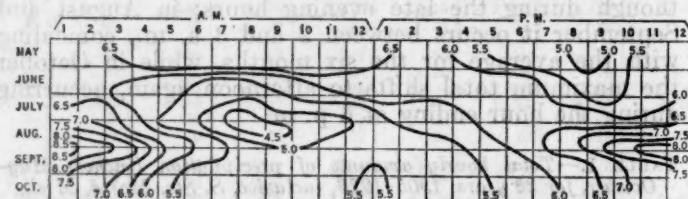


FIG. 4.—Percentage frequency of 0.10 inch or more precipitation within six-hour period beginning at 12 midnight, 1 a. m., 2 a. m., etc. Data from 22 years' records Sault Ste. Marie.

In the latter, 0.01 of an inch, the smallest measured quantity, was made the basis, and the time period was one hour. In the present calculation the basis of quantity has been increased to cover 0.10 or more; the time period, while including that for a single hour, also covers groups of hours, 2, 3, 4, 5, and 6. For example, in May

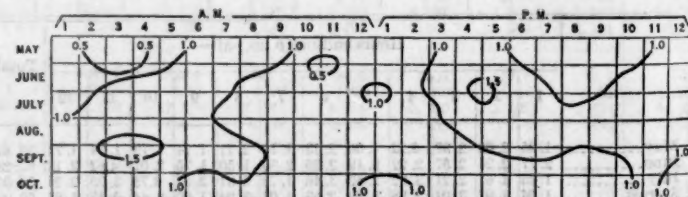


FIG. 5.—Hourly frequency of 0.10 inch or more precipitation. Data for 22 years, 1905 to 1926, Sault Ste. Marie (0.10 within one hour)

the single hour beginning at midnight has a frequency of 0.9, the two hours beginning midnight (or from 12 to 2 a. m.) has a frequency of 1.6, the three hours 12 midnight to 3 a. m. a value of 2.4, etc., while the six-hour period 12 to 6 a. m. has a frequency of 6. Taking the values by months it is found that in May the six-hour

period beginning at 3 a. m. has the highest frequency of the 24 possible groupings, the least frequency occurring in the six hours beginning at 5 p. m. In a similar manner it is possible to determine, in so far as the past performance of 22 years can form a basis, the frequency of precipitation of 0.10 of an inch or more, for the six months when recording instruments are not interfered with by freezing temperatures. The mean values for the May-October period show a maximum frequency over 3 and 4 hours beginning at 2 a. m.; that is, from 2 to 5 a. m. and 2 to 6 a. m., respectively, the maximum for five hours falling within the period from 1 to 6 a. m., while for six hours, the most favorable grouping is that from midnight to 6 a. m. Unlike the values given in Table 3, little chance is present in this latter frequency computation for misinterpreting the several results given, inasmuch as the basis of 0.10 inch is sufficiently high to cover insurance claims, thereby satisfying the main purpose of

the study. One exception should be noted, however, namely, that frequency values for a single hour, shown as the first item in Table 4, are not to be accepted with the same confidence as those covering longer periods, due to the small number of observations in which 0.10 of an inch of precipitation has occurred in one hour. Finally, it should be observed that in applying the frequency values to any particular problem, the fact that the hour of maximum frequency has been set in bold-faced type should not prejudice one to overlook other values, often but a point or so lower in the scale and for practical purposes often of equal significance. For example, in the last row of values for June, covering the six-hour grouping, though the maximum frequency of 7.3 occurs near midnight, other high values of 7 occur beginning at 5 a. m. and 9 a. m. In this case the two secondary maxima are sufficiently high to warrant considering them as well as the extreme maximum for the 24 hours.

TABLE 4.—Percentage frequency of the occurrence of 0.10 inch or more precipitation within 1, 2, 3, 4, 5, and 6 hours beginning at midnight, etc., for 24 hours at Sault Ste. Marie, Mich. (years 1905-1926, inclusive)

Month	Length of period (hours)	Period beginning (a. m.) at—											Month	Length of period (hours)	Period beginning (p. m.) at—												
		Midnight	1	2	3	4	5	6	7	8	9	10	11		12	1	2	3	4	5	6	7	8	9	10	11	
May	1	0.9	0.4	0.4	0.6	0.4	0.9	1.2	1.0	1.0	0.7	0.3	0.4	May	1	0.4	0.6	0.9	1.0	0.6	0.4	1.0	0.3	0.4	1.0	0.3	
	2	1.6	1.5	1.9	2.2	1.9	2.8	2.4	2.2	2.1	1.6	1.0	1.0		2	1.6	2.1	2.5	2.1	2.1	1.2	2.1	1.6	1.3	1.3	2.1	1.5
	3	2.4	2.6	3.1	3.2	3.5	4.0	3.7	3.1	2.9	2.9	2.4	2.2		3	2.6	3.2	3.4	3.8	2.8	2.8	2.4	2.1	2.1	2.2	2.9	1.8
	4	3.2	4.0	4.9	4.7	4.4	5.3	4.4	4.4	4.3	3.7	3.5	4.0		4	4.7	4.3	4.9	3.8	3.7	3.1	3.2	2.2	2.9	2.6	3.1	3.2
	5	4.9	4.7	5.6	5.5	5.9	5.7	5.6	5.9	5.7	5.1	4.9	5.5		5	5.5	5.6	5.5	5.1	4.4	3.7	3.7	3.5	3.7	3.5	4.1	3.7
	6	6.0	6.5	6.5	7.1	6.3	6.5	6.9	6.8	6.0	6.6	6.8	6.2		6	6.3	6.7	6.2	5.7	4.9	4.4	5.0	4.4	4.4	4.6	4.7	6.1
June	1	0.6	0.5	1.1	0.9	1.1	1.5	1.4	0.6	1.7	0.6	0.5	1.1	June	1	1.1	1.1	1.2	1.2	1.7	1.2	1.2	0.5	0.8	0.8	1.7	0.9
	2	1.4	1.5	2.4	2.3	2.6	2.1	2.4	2.6	2.7	1.7	2.1	2.4		2	2.0	2.6	2.1	3.2	2.7	2.9	2.1	2.1	2.1	2.9	2.9	2.4
	3	2.9	2.4	3.3	3.5	3.3	3.5	4.2	3.5	3.8	3.0	3.5	3.3		3	3.8	3.3	3.9	4.2	3.8	3.8	3.8	2.9	3.5	3.3	3.5	2.6
	4	3.9	3.5	4.5	4.1	4.4	5.0	4.7	4.4	4.7	4.1	4.2	4.7		4	4.5	4.8	4.7	4.7	4.2	4.5	4.1	3.9	3.9	3.9	3.9	4.2
	5	5.0	5.0	5.0	5.2	5.9	5.9	5.9	5.4	5.8	5.3	5.9	5.9		5	5.6	5.8	5.6	5.4	5.2	5.0	5.0	4.1	4.4	4.2	5.0	4.7
	6	6.8	6.6	6.5	6.5	6.8	7.0	6.5	6.4	6.8	7.0	6.7	6.7		6	7.0	6.7	5.9	6.4	6.9	6.2	5.8	5.3	5.4	6.5	7.3	6.2
July	1	0.7	1.3	1.3	1.0	1.3	1.0	0.4	0.6	0.1	0.6	0.6	1.0	July	1	0.7	0.7	1.3	1.2	1.8	1.6	0.7	1.2	1.2	1.3	1.5	0.9
	2	2.2	2.1	2.2	2.4	2.5	1.9	1.2	0.7	1.0	1.8	1.9	1.9		2	2.1	1.5	2.5	2.6	3.1	2.5	2.2	2.8	3.1	2.2	2.1	1.8
	3	3.2	3.1	3.5	3.4	2.9	2.5	1.5	1.5	2.1	2.8	2.9	2.8		3	2.8	2.6	3.5	3.8	3.7	3.5	3.4	4.4	3.7	3.2	2.5	2.5
	4	4.1	5.0	4.0	3.8	3.5	2.5	2.4	2.4	3.2	3.7	3.5	3.4		4	3.8	4.0	5.0	4.3	4.6	4.7	5.0	4.9	4.0	3.4	3.2	3.4
	5	5.6	5.9	5.3	4.7	4.1	3.5	3.1	3.4	3.7	4.3	4.6	4.6		5	4.9	5.0	5.0	4.7	5.3	5.6	5.1	5.6	4.6	4.3	4.4	4.4
	6	6.0	6.2	5.7	4.7	4.4	3.8	3.7	4.0	4.7	5.1	5.4	5.4		6	6.2	5.4	5.9	6.2	6.8	6.5	6.0	5.7	5.0	4.7	4.7	5.1
August	1	0.7	1.3	1.8	1.0	1.5	1.3	1.3	0.7	1.3	1.0	0.6	0.7	August	1	0.3	0.7	0.6	1.2	0.9	1.3	1.5	1.2	0.7	1.8	1.0	1.3
	2	2.5	3.2	2.9	2.5	3.5	3.7	2.6	2.1	1.8	1.8	1.3	1.3		2	1.5	1.8	2.2	1.5	2.2	2.1	2.8	2.4	3.2	2.4	2.8	2.2
	3	4.3	4.3	4.6	4.6	4.6	4.7	3.2	2.9	2.9	2.6	2.1	2.4		3	2.6	3.1	2.6	2.6	3.1	3.1	3.4	3.8	3.6	3.5	3.2	3.7
	4	5.0	5.4	5.9	5.3	5.3	5.4	4.4	3.5	3.5	2.9	2.9	3.7		4	3.7	3.1	4.0	4.0	3.8	3.7	4.7	4.7	4.9	4.6	4.4	5.3
	5	6.2	6.8	6.5	6.0	6.0	5.7	4.7	4.1	3.8	3.8	3.7	4.1		5	5.8	4.6	5.1	4.7	4.9	5.6	5.6	6.2	5.9	5.6	6.0	6.0
	6	7.6	7.4	7.4	6.6	6.5	6.2	5.3	4.6	4.7	4.4	4.4	4.6		6	6.1	5.3	6.0	5.4	6.3	6.3	6.6	6.8	6.8	7.6	7.0	7.4
September	1	1.5	1.1	2.0	1.7	1.5	0.9	1.2	1.4	0.5	0.8	1.1	1.1	September	1	1.5	1.2	0.6	0.9	0.9	0.8	0.9	1.1	0.8	1.4	1.5	1.5
	2	3.6	3.9	3.8	3.5	2.9	2.7	2.4	1.8	1.2	1.4	2.1	2.4		2	2.1	2.4	1.8	1.7	1.8	1.7	1.8	2.3	2.6	2.7	2.7	2.9
	3	5.6	4.8	5.6	4.4	3.0	2.9	2.7	2.7	1.8	2.4	3.0	3.0		3	3.8	3.3	2.7	2.1	2.1	2.7	3.2	3.5	3.8	4.1	4.2	4.7
	4	7.1	6.5	7.0	5.8	5.8	4.8	4.1	3.0	3.0	3.8	4.2	4.4		4	4.4	4.4	3.6	2.9	3.3	3.9	4.5	4.7	4.7	4.8	5.9	6.7
	5	8.6	7.7	7.6	7.9	6.4	5.6	4.8	4.8	4.4	4.5	4.8	4.8		5	5.3	5.0	4.2	3.8	4.2	4.5	5.8	5.4	6.1	6.7	8.3	8.3
	6	10.0	8.9	9.5	7.9	6.7	5.8	5.9	5.6	5.3	5.6	5.9	5.9		6	5.9	5.4	5.0	5.0	5.3	6.1	6.5	7.0	7.7	9.4	9.2	10.0
October	1	1.5	1.0	0.4	0.4	0.9	0.7	1.2	0.9	0.7	0.7	0.6	0.6	October	1	0.6	0.6	0.9	1.0	1.0	0.6	0.4	0.4	0.6	0.9	0.7	0.3
	2	2.4	1.5	1.5	2.2	2.2	2.2	1.9	1.8	1.8	1.9	1.9	1.5		2	1.3	1.6	2.6	2.4	2.4	1.2	1.2	1.6	2.1	2.2	1.9	2.1
	3	3.5	2.2	2.4	2.9	2.9	2.8	3.1	2.8	2.5	2.8	2.6	2.5		3	2.5	2.8	3.4	4.3	3.5	2.6	2.2	2.9	2.8	3.1	2.9	2.5
	4	3.4	3.4	3.4	3.4	3.7	3.8	3.2	3.4	3.5	3.8	3.4	3.4		4	3.7	3.7	5.1	5.1	3.8	3.4	3.4	3.7	3.4	3.4	3.4	3.5
	5	4.1	5.0	4.0	4.3	3.8	3.8	3.8	4.3	4.1	4.7	4.6	4.4		5	4.6	5.0	5.3	4.4	4.6	4.6	4.1	4.6	4.9	4.6	4.3	4.0
	6	5.7	5.1	4.9	4.7	4.1	4.3	4.6	5.4	5.1	5.4	4.7	4.9		6	5.9	5.1	5.7	5.7	6.2	5.4	5.1	5.6	5.1	5.3	4.9	4.3
Means	1	1.0	0.9	1.2	0.9	1.1	1.0	1.1	0.9	0.9	0.7	0.6	0.8	Means	1	0.8	0.8	0.9	1.1	1.2	1.0	0.8	0.9	0.7	1.1	1.2	0.9
	2	2.3	2.3	2.4	2.4	2.6	2.2	2.2	1.9	1.8	1.8	1.8	1.8		2	1.8	2.0	2.3	2.2	2.4	1.9	2.0	2.1	2.4	2.3	2.4	2.2
	3	3.5	3.2	3.8	3.7	3.5	3.6	3.1	2.7	2.7	2.8	2.8	2.7		3	2.9	3.0	3.2	3.5	3.2	3.1	3.1	3.3	3.3	3.2	3.2	3.0
	4	4.4	4.6	5.0	4.5	4.6	4.4	3.9	3.5	3.7	3.7	3.6	3.9		4	4.1	4.0	4.6	4.0	3.9	3.9	4.2	4.0	4.0	3.8	4.0	4.4
	5	5.7	5.8	5.7	5.6	5.4	4.9	4.6	4.6	4.6	4.6	4.8	4.9		5	5.0	5.2	5.3	4.7	4.8	4.8	4.7	4.9	4.9	4.8	5.4	5.2
	6	7.0	6.6	6.8	6.2	5.8	5.6	5.8	5.4	5.4	5.7	5.6	5.6		6	6.1	5.6	5.8	5.7	6.0	5.8	5.8	5.7	6.4	6.3	6.4	

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WATER-LEVEL MOVEMENTS AS AN INDICATOR OF FOREST-FIRE WEATHER¹

By DAVID G. THOMPSON

The water-level movements in a well as obtained by automatic gage, have been put to a new use in New Jersey. In an attempt to determine what constitutes "good fire weather" and predict the likelihood of forest fires, Mr. A. D. Follweiler of the forestry division of the State department of conservation and development has been making a study of the relation between meteorologic conditions and the number and size of fires each day during the fire seasons, which occur in the spring and fall. Observations are being made of barometric conditions, precipitation, relative humidity, wind velocity and direction, temperature, and sky conditions.

On certain days when other conditions indicated the fire hazard to be great, the number of fires was unexpectedly small and the question arose as to the influence of soil moisture in keeping the underbrush damp. A study of the record of the fluctuation of water level in a shallow well, in which the water level ranges $3\frac{1}{2}$ feet to less than 1 foot below the surface, showed that on these

days the water level was high. Recently, when the water level was lower, there were bad fires. The well record is now being furnished regularly to the forestry division.

The nearness of the water level to the surface in the locality of the observation well probably does not in itself exert a direct influence in preventing fires, for even within a few hundred yards, due to surface configuration, the water table lies so far below the surface that there can be no upward capillary movement to keep the surface moist. Rather, it is merely an indication of general moisture conditions. Doubtless it would be more significant to make determinations of the moisture content of samples of the surface foot of soil in localities where the water table is both near the surface and at a considerable depth below it, but it has not been possible to do this.

A comparison is also being made between the stream-flow and the number of fires. So far this seems to indicate a relation similar to that existing in the comparison with ground water conditions, presumably because the ground-water and surface-water conditions are so interrelated.

¹ Communicated to the editor by the Director of the U. S. Geological Survey. Mr. Thompson is a geologist in the water resources branch of that survey.—Ed.

TORNADOES IN KANSAS, JULY 16, 1927

[Condensed from reports furnished by P. Connor and B. R. Laskowski]

Kansas City and vicinity.—The morning weather map showed a zone of relatively low pressure about 500 miles wide from Lake Superior southwest to the Texas Panhandle, with readings ranging from 29.80 to 29.90 inches. An area of high pressure overspread the Southeast and another was centered over the northern Rocky Mountain region. The line of demarcation between the surface air drifts from the north and the south, extended directly from a little east of St. Paul and Duluth southwestward a little west of Omaha, Concordia, Dodge City, and Amarillo.

The morning temperatures were ordinary generally, perhaps a little below normal. Rains occurred the night before in the middle Missouri Valley and Minnesota, while clear sky appeared over the Southwest.

Locally, it was a day of uncertain weather, cloudy until 1 p. m. with a thunderstorm in forenoon. Then the clouds began to clear away as if all trouble had passed, only to reassemble again before 4 p. m., leading to the approach of a thunderstorm from the west of rather ominous appearance.

The first thunder was heard at 4:10 p. m. Rain began at 4:17 and ended at 5:27 p. m., the total amount being 0.34 inch. The wind was gentle. There was nothing in the instrumental registration in the Weather Bureau office to indicate that anything of a destructive character had taken place.

The tornado formed about 1 mile west of Monrovia, a small farm and gardening settlement in Johnson County, Kans., at 4:45 p. m.

No one reported having seen a funnel-shaped cloud, but a few persons claimed to have seen a "whirling cloud dip and bounce."

According to many witness the storm had been threatening for some time. Thunder was heard a half-hour before the tornado formed. From Monrovia witnesses saw two great black clouds traveling from opposite directions which "met with a crash of thunder." The air suddenly became oppressive and a copperish haze spread over the scene of "collision." Some heard a moan, others the noise of a train. Most of them, however, were not

alarmed by what they heard, taking it for the approach of a thunderstorm.

It was preceded by a rather heavy downpour of rain.

From Monrovia the tornado traveled about 3 miles northeastward, a little to the north of Shawnee and Merriam, Kans., to South Park, a small settlement along the Kansas City-Olathe Highway, about 2 miles southwest of Rosedale, Kans., where it caused its greatest destruction, and apparently where its energy dissipated. Its path was about 4 miles long and about 600 feet wide.

Some persons and newspapers have stated that it reasserted itself a little later in the extreme southern part of Kansas City, Mo., where quite a little damage was done, beginning about Eighty-third and Main Streets, and extending about $1\frac{1}{2}$ miles northeastward, its path being about 500 feet wide.

The writer, although admitting the possibility of this, is unwilling to accept the statement as a fact, for the reason that in order to have done so, it would have had to be transposed at the cloud level nearly 6 miles on a southeast line, from where it disappeared on the Kansas side while moving in a northeast direction. The writer would prefer assuming that it was a result of a secondary concentration of forces, an independent development, which visited the southern section of Kansas City, Mo., as the parent disturbance moved eastward.

Damage first began at Monrovia. From there to the edge of South Park the ground is high, a country district. Two dwellings were totally destroyed and about 18 damaged. Several barns and chicken houses were wrecked; large limbs of trees were torn off here and there and a few trees blown down.

South Park is in a narrow valley. The houses are small, in most cases frail frame structures; a few stucco cottages and there was one 2-story brick building, part stores and part dwelling quarters.

About 20 dwellings were destroyed and about 35 others had the sides torn off, the whole or parts of roofs and porches were carried away and chimneys were blown down. Some large trees were uprooted and large limbs were broken off the trunks of many others. There was

very little evidence of the foliage having been stripped from the trees.

In Kansas City, Mo., the tornado began its work of destruction in the neighborhood of Eightieth to Eighty-third and Main Streets, 3 small houses being demolished and about 10 damaged. In the vicinity of Troost and Tracy Avenues it practically destroyed a frame store and considerably damaged a few houses. Farther along its northeastward course of about $1\frac{1}{2}$ miles, it damaged a house slightly here and there and broke off some limbs of trees to about Sixtieth and the Paseo, where its force became exhausted.

CASUALTIES

In Kansas.—Four killed; 40 injured, several dangerously; 100 rendered destitute. Property damage: 22 dwellings demolished; 53 damaged, some quite badly. Estimated property damage, \$150,000, plus \$10,000 damage sustained by the Southwest Bell Telephone Co.

NOTES AND ABSTRACTS

ON THE MECHANISMS OF CYCLONES AND ANTICYCLONES¹

By T. KOBAYASI

The author points out that, according to the Bjerknes theory, two air currents from different sources meet in a cyclone and consequently the latter is always accompanied by two lines of discontinuity. In actual cases, however, it is further pointed out, some cyclones lack one or both such lines whence the author considers cyclones as circular vortices and seeks to find the causes from which lines of discontinuity are formed.

His studies lead him to consider as the much more plausible of the theories of the mechanism of a cyclone that one which gives the circulation up to 2 to 4 km. a form resembling that of a vortex in a stream. He has calculated for many cyclones the height at which they acquire this character and finds the level in winter to be between 2 and 3 km. and in summer between 2.5 and 4 km. and these heights he considers as the limits of the atmosphere influenced by the temperature at the earth's surface by means of turbulence and convectional motions. The full account is to be published in Rep. Aeronaut. Research Inst. Tokyo Imp. Univ. Vol. II, No. 20.—A. J. H.

RECORDER OF FREQUENCY OF ATMOSPHERICS: ITS USE IN METEOROLOGY²

By R. BUREAU, A. VIAUT, and A. GRET

(Abstract reprinted from *Science Abstracts*, May 25, 1927, 1308, pp. 372-373)

In the apparatus used each atmospheric functions a relay, and a current is conveyed through an electromagnet to operate the recording part. A curve is traced whose ordinates are proportional to the frequency of the atmospheric. The curves between August and December, 1926, covered many types of atmospheric and many meteorological situations, but a sharp relationship is shown between the passage of surfaces of discontinuity and the evolution of atmospheric.

In one striking case the atmospheric coincided exactly with the moment at which each of a series of squalls passed over.

¹ In Proceedings Imperial Academy, Japan 3: no. 2, p. 72.² Comptes Rendus, 184: 157-158, January 17, 1927.

In Kansas City, Mo.—No casualties of a personal nature. Property damage: Four small houses wrecked and 16 others more or less damaged. Estimated loss about \$25,000.—P. Connor.

Wabaunsee and Morris Counties.—A tornado was observed between 4 and 4:30 p. m. 6 miles northeast of Harveyville, in the southeast corner of Wabaunsee County; it moved thence east-southeast over a path 12 miles long and 60 rods wide to the northeast part of Burlington County, where it disappeared. The greatest damage was inflicted in the last 3 miles of its path. A second tornado was observed at 4:15 p. m. a mile northeast of Dunlap in Morris County. This point is about 30 miles southwest of the point of origin of the tornado first described; it also moved in an east-southeast direction over a path about 28 miles long and from a few feet to 50 feet in width. Further details regarding all of these storms is given in table on page 337.—B. R. Laskowski.

It is concluded that (1) the source of a very great number of atmospheric, is in the atmosphere in the immediate vicinity of the wireless-telegraph station, and (2) registrations of atmospheric form one of the most powerful means for the analysis of the detained structure of the meteorological discontinuities, and, in particular, the principal and secondary cold-front discontinuities.—R. S. R.

NEW IRRIGATION PROJECTS IN ARIZONA AND NEW MEXICO¹

Larger and larger areas of desert land are being reclaimed in Arizona by the building of a chain of dams in Salt River and its tributaries for the further conservation and use of water both for power and irrigation. The two separate and distinct uses are made possible by the very simple expedient of constructing a low diversion dam immediately below the power house at the foot of the storage dam so that the water after passing through the turbines is again caught and diverted for irrigation purposes.

The Roosevelt dam—a Federal project—was completed in 1911. Since that time a chain of dams below it have been completed, that known as Horse Mesa, which backs water up to the foot of the first-named being the most recent. Dams downstream from Horse Mesa are Mormon Flat, Stewart Mountain, Granite Reef, and Joint Head diversion.

What is to be known as Lake Pleasant, a body of water 8 miles long and 2 wide, impounding 173,500 acre-feet for the irrigation of 40,000 acres of land, has been created on the Agua Fria River near Phoenix, Ariz.

Another privately financed project is that known as Bluewater-Toltec of Valencia County, N. Mex. This project includes a storage dam at the head of Bluewater Canyon that will impound 53,000 acre-feet and provide irrigation for 10,000 acres of land.

A beginning has been made in the construction of the Coolidge Dam, San Carlos project, Ariz. This dam when completed will store 1,285,000 acre-feet.

¹ Condensed from *Modern Irrigation*, June, 1927.

WORLD WEATHER RECORDS¹

This octavo volume of 1,200 pages will be welcomed as one of the most helpful contributions to world meteorology that has appeared in recent years. It was prepared in response to a need expressed by the International Meteorological Committee at Utrecht in 1923. The resolution follows:

13. (4) V. Considering Professor Exner's proposal about the calculation of the correlations between weather anomalies in regions far from each other, the conference thinks that publication of long and homogeneous series of observations in the form of monthly means of pressure, temperature, and rainfall would be of the highest importance for the study of the general circulation of the atmosphere. This publication should comprise a small number of stations at a mutual difference of 500 to 1,000 kilometers, preferably belonging to the Réseau Mondial, and if these should fail, other stations with a longer homogeneous series. It proposes that the various meteorological institutes should establish such series up to the year 1920 and invites the following gentlemen to see to the execution of this resolution: Doctor Walker for the stations of Asia; Professor Exner for the stations of Europe; Mr. Clayton for the stations of America; Doctor Simpson for the stations of Africa, Australia, and the oceans.

The volume contains the record of monthly means of pressure and temperature and the monthly totals of precipitation for about 400 stations. The period of years covered is in the main the second half of the nineteenth century, or more specifically from the early seventies to 1920.

The geographical distribution of the stations follows very closely that of the Réseau Mondial.

The data were assembled and arranged by the well-known meteorologist, H. Helm Clayton. The arrangement is excellent and the typography is as nearly faultless as is humanly possible.

Meteorologists the world over are under obligations to Mr. John A. Roebeling who financed the printing of the volume.

The committee is to be congratulated on the promptness with which the task assigned to it was completed.—
A. J. H.

METEOROLOGICAL SUMMARY FOR SOUTHERN SOUTH AMERICA, JUNE, 1927

By J. BUSTOS NAVARRETE, Director.

[Observatorio del Salto, Santiago, Chile]

In the central and southern regions of Chile the month of June was generally rainy, but the amounts of precipitation were less than those of the preceding year. At Santiago the rainfall during the first half of 1927 amounted to 8.35 inches (212.1 mm.) in contrast to 19.22 inches (488.3 mm.) for the same period of 1926. In the southern region, however, the amount of rainfall was about the same as in 1926. At Valdivia the precipitation received during the first half of 1927 was 33.39 inches (848.2 mm.).

The atmospheric circulation was stronger in the first than in the second half of the month. The principal anticyclones, marking the periods of fair, cold weather, were noted as follows: 2d to 6th, 10th to 13th, 18th to 20th, and 22d to 31st. The principal cyclonic depressions, causing the storms and rains of the month, were those of the 1st, 2d, to 3d, 6th to 8th, 9th to 10th, 14th to 16th, 21st to 22d, and 28th to 29th.

The area with rainfall was the region extending from the Province of Atacama on the north to the Province of

Magallanes on the south. The greatest monthly amounts of precipitation were recorded in the region of Valdivia.

The most notable phenomena of the month were the great storms near the beginning of the month in the Provinces of Coquimbo and Atacama, the region near the desert, and the great waterspout in the city of Ancud, Chiloe, destroying more than 100 houses and bringing serious injury or death to many inhabitants.—*Transl.*: W. W. R.

Note.—At Caldera on the coast of the Province of Atacama the precipitation for June 1-3 was 3.03 inches—five times the normal annual amount and nearly twice the greatest annual amount in 25 years (1.76 inches in 1905).

METEOROLOGICAL SUMMARY FOR BRAZIL, JUNE, 1927

By J. DE SAMPAIO FERRAZ, Director

[Directoria de Meteorologia, Rio de Janeiro]

The secondary circulation in this month over the meridional and central parts of South America was remarkably active. Six rapid anticyclones and frequent passages of the high latitude depressions kept up extremely changeable charts and very unstable atmospheric conditions.

The River Plate and southern Brazil were visited by several storms and large variations of temperature and rainfall. In the middle of the month the continental depression was particularly active. Frosts were observed in southern Brazil in the middle and end of the month.

Rainfall continued below normal throughout the country except in the southern sections and some restricted regions of the north. In south Brazil precipitations were generally abundant and in some cases excessive.

Rio de Janeiro had a fairly normal month except in the general weather conditions, which were too unsettled for the season.

Crops generally doing well.

JULY WEATHER IN OTHER COUNTRIES

[Extracts from cabled reports to Department of Commerce]

Mexico.—There was continued drought throughout the Republic, with the exception of a few districts during the first months of the year, which unfavorably affected crops in the northern and north-central part of the country. Pasture lands have also been badly affected by the drought and it is stated that large numbers of cattle are perishing from lack of water and pasturage.

Australia.—The seasonal outlook in all States except Western Australia is unpromising unless further rains come. During the past two months the rainfall has been below the average, but there is yet time for good penetrating rains to relieve the situation.

Jamaica.—Excellent weather conditions have made agricultural interests more prosperous.

Venezuela.—Extraordinarily heavy rains are causing serious floods in several regions of the interior of Venezuela and considerable areas of cultivated lands adjacent to the rivers are inundated.

Argentina.—Satisfactory weather conditions offer a favorable agricultural outlook.

Chile.—Continued heavy rains throughout the month caused a slowing up of purchases of agricultural instruments.

Honduras.—Rains throughout the entire Republic have been plentiful and have occurred at the time most helpful to the crops.

¹ Smithsonian Miscellaneous Collections, vol. 79 (whole volume), World Weather Records, collected from official sources and published by the Smithsonian Institution under a grant from Mr. John A. Roebeling.

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SOLAR OBSERVATIONS

SOLAR AND SKY RADIATION MEASUREMENTS
DURING JULY, 1927

By HERBERT H. KIMBALL

For a description of instruments and exposures and an account of the method of obtaining and reducing the measurements the reader is referred to the REVIEW for January, 1924, 52:42, January, 1925, 53:29, and July, 1925, 53:318.

From Table 1 it is seen that solar radiation intensities averaged above the July normals at all three stations.

Table 2 shows an excess in the total solar radiation received on a horizontal surface from the sun and sky at all three stations for which normals have been determined, which was pronounced at Madison and Lincoln.

Skylight polarization measurements made at Washington on two days give a mean for 56 per cent, with a maximum of 57 per cent on the 28th. At Madison measurements obtained on seven days give a mean of 57 per cent, with a maximum of 69 per cent on the 2d. These are close to the corresponding averages for July at both Washington and Madison.

TABLE 1.—Solar radiation intensities during July, 1927

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance										Local mean solar time	
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°		Noon
	75th mer. time	Air mass										
		A. M.					P. M.					
		e.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0		5.0	e.
July 1	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.	
5	9.83					1.27	1.02	0.90			14.10	
12	7.57		0.80	0.95	1.13	1.39					11.38	
13	17.96					1.20					19.89	
20	20.57			0.75							22.00	
26	16.20					0.83					13.13	
27	16.79					0.78					16.79	
28	16.79				0.73	0.99					17.37	
Means			(0.80)	(0.85)	(0.93)	1.08	(1.02)	(0.90)				
Departures			+0.14	+0.08	+0.04	-0.09	+0.04	+0.12				

Madison, Wis.

July 1.....	17.37			0.77		1.24	1.44				16.79
2.....	10.59					1.18	1.38				10.59
6.....	13.61		0.91	1.02		1.15	1.35				17.96
18.....	11.81				1.11	1.34					12.24
19.....	7.87					1.39					9.47
20.....	8.18										8.81
23.....	11.81				0.98	1.30					10.21
25.....	11.81				0.92	1.20					12.24
26.....	13.61				0.89						13.13
27.....	13.13				0.93	1.14					12.24
28.....	16.20				1.16	1.23					17.37
29.....	10.97				1.10	1.31					8.81
Means.....			(0.91)	(0.90)	1.06	1.30					
Departures.....			+0.14	+0.00	+0.01	+0.02					

Lincoln, Nebr.

July 1.....	14.10				1.40	1.23	1.08	0.97			12.24
2.....	11.35			1.04	1.19	1.36					10.97
3.....	9.47				1.32	1.09	0.91	0.77	0.65		12.24
4.....	13.61		0.79	0.93	1.15	1.35					13.13
7.....	11.35			1.17	1.31	1.46					11.35
8.....	11.35			0.93	1.09		1.10	0.99	0.84		12.24
9.....	13.61				1.39	1.17	0.99	0.84			12.24
23.....	10.97				1.09	1.28					9.83
25.....	12.68			1.01	1.18	1.38					12.68
26.....	12.68		0.84	1.00	1.14	1.35	1.03	0.82	0.66		13.61
27.....	15.65		0.77	0.90	1.11	1.33					14.60
Means.....			0.80	1.00	1.16	1.36	1.12	0.95	0.81	(0.65)	
Departures.....			+0.00	+0.10	+0.08	+0.03	+0.06	+0.07	+0.07	-0.07	

¹ Extrapolated.

TABLE 2.—Solar and sky radiation received on a horizontal surface

[Gram-calories per square centimeter of horizontal surface]

Week beginning	Average daily radiation						Average daily departure from normal		
	Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Washington	Madison	Lincoln
1927	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
July 2.....	513	586	667	583	441	719	+37	+50	+87
9.....	456	475	568	384	370	750	-24	-57	-23
16.....	419	523	558	387	271	727	-49	+11	-18
23.....	516	557	591	467	374	607	+47	+68	+50
Deficiency since first of year on July 29.....							-7,630	-4,424	-5,285

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. Edwin T. Pollock, Superintendent U. S. Naval Observatory]

[Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, and Mount Wilson observatories]

Date	Eastern standard civil time	Heliographic		Area ¹	
		Longi- tude	Latitude	Spot	Group
1927					
July 1 (Naval Observatory).....	<i>h. m.</i> 11 47	° -60.5 -49.0 -4.0 +9.0 +46.0 +75.0	° +15.0 +16.5 -9.0 -8.0 +22.0 +21.0	93	340 432 123
July 2 (Naval Observatory).....	11 50	-66.5 -48.0 -37.0 +22.5 +32.5 +58.0	-10.0 +14.5 +16.0 -8.0 +23.5 +22.5	62 15	31 370 463 46 154
July 3 (Naval Observatory).....	11 58	-52.5 -34.0 -23.0 +35.5 +44.0 +72.0	-10.0 +14.5 +16.0 -8.0 +23.0 +22.5	15	15 432 494 62 139
July 4 (Naval Observatory).....	11 47	-77.0 -39.0 -10.0 +49.0 +59.0	-11.0 -10.0 +15.5 -8.0 +22.5	12	62 370 463 62
July 5 (Naval Observatory).....	11 53	-63.0 -53.0 -25.0 +4.0 +64.0 +73.0	-11.0 -7.5 -10.0 +15.5 -8.0 +22.5	15 12	401 463 62 10 30 448
July 6 (Mount Wilson).....	10 30	-46.5 +16.5 +78.0	-10.0 +14.0 -7.5		737 294
July 7 (Naval Observatory).....	12 10	-37.0 -26.5 +12.5 +30.0 +62.0	-10.5 -7.0 -10.5 +15.0 +21.0	31 15	15 432 31
July 8 (Naval Observatory).....	11 47	-72.0 -22.0 -13.5 +44.0	-11.0 -12.0 -8.0 +17.5	46 15	15 401
July 9 (Mount Wilson).....	10 30	-75.0 -59.5 -50.0 -5.0 +2.0 +56.0	+25.0 -7.0 -22.5 -9.0 +12.5 +14.0	3 14	10 30 2 448
July 10 (Mount Wilson).....	9 50	-64.0 -46.0 -37.0 -7.5 +17.0 +71.0	+25.0 -7.0 -23.5 -8.5 +12.5 +14.0	2 11	8 27 3 240
July 11 (Naval Observatory).....	11 52	-32.0 -22.0 +84.0	-7.5 -23.0 +16.0	15 9	309 31
July 12 (Naval Observatory).....	11 50	+37.0	+10.5		19
July 13 (Naval Observatory).....	11 48	-72.5 +52.0	-12.5 +10.5	123	
July 14 (Naval Observatory).....	11 42	-68.0 -59.0	-14.0 -13.0	15 216	
July 15 (Naval Observatory).....	11 57	-71.0 -55.5 -46.5 -11.5	-30.5 -14.0 -13.0 +14.0	62 12	216 46 15
July 16 (Naval Observatory).....	11 43	-60.0 -32.0 +2.0 +50.5	-30.5 -12.5 +14.5 -12.0	154	77 108

¹ Areas are corrected for foreshortening and are expressed in millionths of Sun's visible hemisphere.

Positions and areas of sun spots—Continued

Date	Eastern standard civil time	Heliographic		Area	
		Longi- tude	Latitude	Spot	Group
1927—Continued					
July 17 (Mount Wilson).....	h. m.	°	°		
	9 40	-47.0	-30.0	-----	12
		-19.0	-12.0	-----	237
		+14.0	+15.0	-----	26
		+63.0	-12.0	-----	20
July 18 (Naval Observatory).....	11 42	-6.0	-12.5	-----	185
		+27.0	+14.5	-----	31
July 19 (Mount Wilson).....	12 8	-78.0	+23.5	98	-----
		-39.5	-10.0	-----	7
		+9.5	-11.0	-----	170
July 20 (Naval Observatory).....	11 42	-63.5	+23.0	93	-----
		+20.5	-11.5	93	-----
		+25.0	-15.5	15	-----
July 21 (Naval Observatory).....	11 41	-80.0	-9.0	409	-----
		-50.0	+23.0	123	-----
		-11.0	-9.5	-----	62
		+36.0	-14.5	-----	93
July 22 (Yerkes).....	18 0	-35.0	-8.0	25	-----
		-65.0	+24.5	75	-----
July 23 (Naval Observatory).....	11 43	-55.0	-9.0	-----	370
		-24.5	+23.0	123	-----
		+17.0	-9.5	-----	93
		+24.0	+10.0	-----	15
		+64.0	-15.0	-----	185
July 24 (Naval Observatory).....	11 44	-42.5	-8.5	-----	340
		-11.0	+23.0	108	-----
		+29.5	-9.5	-----	46
		+39.0	+9.0	-----	93
		+75.0	-19.0	12	-----

Positions and areas of sun spots—Continued

Date	Eastern standard civil time	Heliographic		Area	
		Longitude	Latitude	Spot	Group
1927—Continued					
July 25 (Naval Observatory).....	h. m. 11 52	° -29.0 +1.0 +42.0 +52.0	° -8.5 +23.0 -9.0 +9.0	340 108 93 77	
July 26 (Naval Observatory).....	11 46	-17.0 -2.0 +14.0 +55.5 +64.5	-9.0 +14.0 +23.0 -9.5 +9.0	370 15 108 108 93	
July 27 (Naval Observatory).....	11 50	-69.0 -2.5 +13.0 +27.5 +70.0	-8.0 -9.5 +14.0 +23.0 -10.0	77 340 46 77 62	
July 28 (Naval Observatory).....	11 49	-56.0 +11.0 +29.5 +40.5 +70.0	-8.0 -9.5 +13.5 +22.5 -17.0	31 309 15 77 9	
July 29 (Yerkes).....	10 19	+42.0 +27.0 +66.5	-29.0 +11.5 +3.5	25 75 10	
July 30 (Yerkes).....	12 16	-30.5 -15.0 +23.0 +52.0 +81.0	-21.5 -7.5 +10.5 -9.5 +22.5	75 15 46 340 309	
July 31 (Naval Observatory).....	13 26				

AEROLOGICAL OBSERVATIONS

By W. R. STEVENS

Average free-air conditions for July, as determined by kites and given in Tables 1 and 2, show close agreement with the normal, except for subnormal temperatures observed at all levels at Ellendale and Royal Center. The airplane station at Washington shows positive temperature departures at all levels. However, only a three-year mean is available at this station. The free-air wind resultants show a slightly more than normal northerly component at Broken Arrow, Ellendale, and Royal Center, and a more southerly component at Due West and Groesbeck.

Easterly winds at high levels were observed at many stations as far north as Ithaca, where a northeast wind of 17 m. p. s. was reported at 10,000 meters on the 1st. They were frequent enough over Key West and San Juan to give an east component in the resultants at all altitudes, and at nearly all altitudes over Groesbeck.

A remarkable pilot-balloon record for the month was made at Medford, Oreg. Sixty-one observations were made, the lowest reaching 4,000 meters. Forty-three of the observations extended to 10,000 meters and 14 to 12,000 meters.

A good illustration of the effect of exchange of mass between different air layers upon the rate of ascent of a pilot balloon is given in the double-theodolite observation made at Groesbeck on the 21st. The balloon ascended with a velocity less than the standard inflation rate to an altitude of 3,600 meters, which indicated a descending current of 0.5 m. p. s. The opposite effect of convection upon the ascensional rate of pilot balloons has been very frequently observed, but descending currents are of much larger cross section than ascending currents; consequently the former have a much lower velocity than the latter, and the observations less frequently prove the existence of descending currents.

Two "free-rising" captive balloon flights were made during the month. This method is quite satisfactory for obtaining free-air observations when winds are too light for kites. Instead of the balloon pulling the wire

out, as is done in kite flying, the wire is reeled out so rapidly that the balloon rises freely, except for the increasing weight of the wire. The Fergusson meteorograph is used, which is described in this REVIEW, p. 293. The ascent at Royal Center attained an altitude of 2,356 meters. A flight was also made at Due West by this method. However, just before reeling in, a kink developed when the wire came to the ground suddenly and the balloon broke away. The balloon and instrument came down undamaged about 12 miles from the station, from whence they were returned. The altitude reached was 5,437 meters.

Meteorological conditions over Due West, S. C., on July 14, 1927

Time	Altitude (m.)	Temperature	Δt 100 m.	Relative humidity	Wind	
					Direction	Velocity
	m. s. l.	° C.		Per cent		m. p. s.
11:22 a. m.	217	28.2		68	WSW	4.5
11:53 a. m.	666	22.8	1.20	77	W	8.0
12:05 p. m.	1,121	21.5	0.29	66	W	8.3
12:29 p. m.	1,676	17.8	0.67	67	WNW	6.4
1:11 p. m.	2,507	12.2	0.65	67	W	8.8
1:33 p. m.	1,576	18.1	0.49	70	W	7.2
1:40 p. m.	1,001	20.9	1.10	88	W	5.0
1:44 p. m.	665	24.6	1.43	74	W	4.9
1:49 p. m.	217	31.0		60	SW	4.0

An unusual number of thunderstorms occurred during the month in the South Atlantic and East Gulf States, Due West reporting them on 22 days, with a total rainfall of 6.61 inches. Thunderstorms which occurred in the afternoon of the 14th in Georgia, South Carolina, and North Carolina are of a type which frequently occur in the Southeast. On this date pressure was high off the South Atlantic coast. The aerological chart shows that the air, to at least moderate altitudes, had come from the Gulf and was very moist. Therefore, in the absence of inversions, a relatively small increase in the surface temperature would produce

instability, since the diurnal change in temperature aloft is much less than at the surface. The flight on this date is a very good example of the gradual building up of an unstable lapse rate in humid air in a high-pressure area, eventually producing a thundershower.

Meteorological conditions over Royal Center, Ind., on July 28, 1927

Time	Altitude (m.)	Temperature	Δ 100 m.	Relative humidity	Wind	
					Direction	Velocity
	<i>m. s. l.</i>	<i>° C.</i>		<i>Per cent</i>		<i>m. p. s.</i>
7:13 a. m.	225	25.6		69	sw	4.9
7:15 a. m.	570	24.1	0.43	68	sw	7.6
7:26 a. m.	934	24.3	-0.05	53	swsw	13.4
7:31 a. m.	1,237	23.0	0.43	59	w	13.8
7:35 a. m.	1,532	20.5	0.85	44	w	16.2
7:41 a. m.	1,819	17.3	1.11	82	w	14.6
7:58 a. m.	2,566	10.9	0.86	76	w	13.2
8:26 a. m.	3,483	3.5	0.81	100	w	14.4
9:07 a. m.	3,940	1.3	0.48	72	wnw	10.3
9:22 a. m.	4,004	-0.3	2.50	100	wnw	10.0
9:47 a. m.	4,069	-0.3	0.00	100	wnw	9.5
9:50 a. m.	4,135	-0.9	0.91	100	wnw	9.8
9:54 a. m.	4,174	-0.2	-1.40	100	wnw	11.4
9:58 a. m.	4,093	-1.0	0.76	109	w	11.4
10:03 a. m.	3,816	1.1	0.30	90	w	14.9
10:12 a. m.	3,717	1.4	0.91	100	w	15.8
10:34 a. m.	2,852	9.3	0.70	76	w	13.8
10:46 a. m.	2,223	13.7	0.87	97	w	14.7
11:08 a. m.	1,239	22.3	0.71	50	w	12.0
11:18 a. m.	490	27.6	2.04	56	swsw	6.3
11:24 a. m.	225	33.0		45	w	5.5

A valuable kite flight to over 4,000 meters was made at Royal Center on the 28th. It was made under threatening conditions and followed by a severe thunderstorm with a rainfall of 1.62 inches. Flights under these conditions to high altitudes are quite rare. This ascent seems unquestionably to furnish an example of an overrunning cold front. This produces a type of upper air convection which probably often occurs in the United States, although examples are very scarce due to the difficulty and danger of obtaining soundings. For a very thorough discussion, see paper by Rossby and Weightman in the MONTHLY WEATHER REVIEW for December, 1926. The conditions which characterize an overrunning cold front are satisfied in this example. We find a cold front extending from Ontario southwestward to Colorado on the morning weather map for this date. A number of thunderstorms occurred during the night considerably in advance of the wind shift line. The region over which they occurred corresponds very well with the area over which the overrunning was taking place. This is very clearly indicated on the aerological

maps, successive levels aloft showing the front displaced farther and farther to the east.

TABLE 1.—Free-air temperatures, relative humidities, and vapor pressures during July, 1927

TEMPERATURE (°C.)												
	Broken Arrow, Okla. (233m.)		Due West, S. C. (217m.)		Ellendale, N. Dak. (444m.)		Groesbeck, Tex. (141m.)		Royal Center, Ind. (225m.)		Washington, D. C. ¹ (7m.)	
Altitude (m.)		De-parture from 9-yr. mean		De-parture from 7-yr. mean		De-parture from 10-yr. mean		De-parture from 9-yr. mean		De-parture from 10-yr. mean		De-parture from 3-yr. mean
	Mean		Mean		Mean		Mean		Mean		Mean	
M. S. L.												
Surface	25.4	-1.2	26.0	-1.1	18.1	-2.9	26.6	-0.2	23.5	-1.4	25.2	+1.2
250	25.3	-1.2	25.7	-1.1			25.9	0.0	23.2	-1.4	23.5	+1.2
500	24.5	-0.5	23.7	-0.7	17.8	-2.8	24.5	+0.4	20.5	-1.6	22.2	+1.2
750	23.5	-0.1	22.1	-0.5	16.7	-2.6	23.1	+0.2	19.1	-1.3	21.0	+1.1
1,000	22.2	0.0	20.6	-0.3	15.8	-2.3	22.0	+0.2	17.6	-1.1	19.5	+1.0
1,250	20.8	+0.2	19.0	-0.2	14.8	-2.2	20.7	+0.1	16.3	-0.8	18.1	+1.1
1,500	19.3	+0.2	17.6	0.0	13.8	-2.0	19.4	+0.1	14.8	-0.8	16.6	+1.1
2,000	16.6	+0.6	14.6	+0.3	11.3	-1.8	16.9	+0.3	11.3	-1.4	13.6	+1.1
2,500	13.5	+0.7	11.4	+0.2	8.6	-1.6	13.8	0.0	8.4	-1.6	10.8	+1.1
3,000	10.3	+0.7	9.5	+1.2	5.7	-1.6	10.2	-0.7	5.7	-1.4		+0.4
3,500	7.4	+0.7	7.3	+2.0	2.9	-1.5	7.5	-0.4	3.3	-1.0		
4,000			5.6	+2.9	0.1	-1.6	4.9	0.0	0.4	-1.1		
4,500			3.4	+3.3	-2.3	-1.5			-2.6	-1.3		
5,000					-4.1	-0.8			-6.0	-1.3		

Surface	75	+6	73	+8	78	+9	75	+2	62	0	69	-4
250	75	+6	73	+8	78	+9	76	+2	62	0	71	-2
500	68	+2	71	+4	77	+9	78	+3	65	+1	68	-1
750	64	0	71	+2	72	+8	77	+3	65	0	66	-1
1,000	64	0	73	+2	69	+7	71	+5	67	0	67	+1
1,250	62	-2	75	+3	68	+8	68	+5	64	-3	65	-1
1,500	60	-3	74	+2	65	+7	66	+4	65	-2	66	-1
2,000	51	-9	72	0	62	+6	57	-2	68	+4	67	0
2,500	50	-9	71	0	60	+6	55	-2	63	+6	64	-2
49	-10	73	62	+10	59	+2	57	-5	63	+6	63	+1
3,500	45	-13	73	+17	60	+8	56	-1	48	-1	48	0
4,000			72	+17	58	+6	53	-8	38	-5	38	-5
4,500			80	+19	50	-2			37	-6	37	-6
5,000					47	0			37	-6	37	-6

Surface . . .	23.86	+0.05	24.28	+1.49		16.08	-0.93	25.95	+0.42	17.68	-1.69	22.23	+0.17
250 . . .	23.64	+0.04	23.87	+1.43				25.44	+0.79	17.45	-1.64	20.65	+0.62
500 . . .	20.74	+0.04	20.69	-0.74	15.59	-0.85	23.97	+1.57	15.50	-1.43	18.09	-0.59	
750 . . .	18.36	-0.22	18.77	-0.38	13.69	-0.57	21.75	+2.05	14.32	-1.17	16.19	+0.44	
1,000 . . .	16.85	-0.12	17.46	-0.41	12.30	-0.45	18.78	+1.64	13.49	-0.82	14.95	+0.70	
1,250 . . .	15.09	-0.34	16.12	-0.42	11.45	+0.45	16.61	+1.63	11.89	-1.04	13.45	+0.43	
1,500 . . .	13.14	-0.72	14.42	-0.25	10.15	-0.06	14.01	+1.22	10.76	-0.81	12.39	+0.36	
1,750 . . .	18.40	-1.60	11.63	-0.10	8.29	+0.01	11.91	-0.18	8.93	+0.01	10.22	+0.23	
2,000 . . .	7.51	-1.33	9.43	-0.22	6.66	-0.07	8.66	-0.53	6.75	+0.21	8.07	-0.03	
2,500 . . .	6.01	-1.13	8.59	-1.12	5.56	+0.12	7.94	-0.15	4.99	+0.02			
3,000 . . .	7.51	-1.33			4.48	-0.05	6.95	-0.33	3.47	-0.48			
3,500 . . .	4.71	-1.13	8.99	+2.83	3.45	+0.26	6.51	+0.56	2.06	-0.85			
4,000 . . .			6.86	+2.05	4.48	-0.77			1.86	-0.75			
4,500 . . .			7.34	+3.24	2.43	-0.52			1.72	-0.75			
5,000 . . .					2.06								

¹ Naval Air Station, D. C.

TABLE 2.—Free-air resultant winds (m. p. s.) during July, 1927

Altitude (m.) m. s. l.	Broken Arrow, Okla. (233 meters)				Due West, S. C. (217 meters)				Ellendale, N. Dak. (444 meters)				Groesbeck, Tex. (141 meters)				Royal Center, Ind. (225 meters)				Washington, D. C. (34 meters)			
	Mean		9-year mean		Mean		7-year mean		Mean		10-year mean		Mean		9-year mean		Mean		10-year mean		Mean		7-year mean	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.
Surface.	S. 7°W.	3.0		3.0	S. 49°W.	0.9	S. 58°W.	1.0	N. 66°W.	1.2	North.	0.3	South.	2.9	S. 18°W.	3.6	N. 63°W.	1.8	S. 82°W.	1.4	N. 68°W.	0.2	N. 30°W.	0.5
250	S. 8°W.	3.2	S. 2°W.	3.1	S. 50°W.	1.3	S. 63°W.	1.1	S. 83°W.	2.4	S. 29°W.	0.8	S. 12°W.	5.8	S. 26°W.	6.0	N. 68°W.	2.0	S. 78°W.	1.5	S. 80°W.	1.4	N. 50°W.	1.2
500	S. 18°W.	5.3	S. 11°W.	4.6	S. 69°W.	2.7	S. 71°W.	1.6	N. 78°W.	1.3	Calm.		S. 9°W.	5.3	S. 25°W.	6.0	S. 88°W.	3.1	S. 72°W.	3.0	N. 37°W.	3.5	N. 66°W.	2.1
750	S. 25°W.	5.3	S. 21°W.	5.0	S. 73°W.	3.2	S. 80°W.	1.9	S. 83°W.	3.1	S. 68°W.	1.4	S. 11°W.	5.3	S. 28°W.	5.8	S. 87°W.	3.4	S. 74°W.	3.8	N. 37°W.	2.9	N. 55°W.	2.5
1,000	S. 34°W.	4.7	S. 28°W.	4.8	S. 74°W.	4.0	S. 85°W.	2.3	N. 88°W.	3.1	S. 56°W.	1.8	S. 12°W.	5.6	S. 28°W.	5.3	West.	3.7	S. 81°W.	4.4	N. 44°W.	3.2	N. 44°W.	3.1
1,250	S. 36°W.	4.0	S. 32°W.	4.5	S. 83°W.	4.1	S. 86°W.	2.6	N. 76°W.	3.3	S. 68°W.	1.8	S. 12°W.	5.6	S. 28°W.	5.8	N. 76°W.	4.8	S. 84°W.	5.2				
1,500	S. 44°W.	3.3	S. 37°W.	4.3	West.	5.5	S. 88°W.	3.7	N. 74°W.	4.4	S. 79°W.	2.6	S. 16°W.	5.2	S. 27°W.	5.0	N. 82°W.	5.5	West.	6.0	N. 48°W.	4.2	N. 55°W.	3.8
2,000	S. 64°W.	2.9	S. 43°W.	3.6	S. 89°W.	7.0	N. 87°W.	5.4	N. 78°W.	6.0	N. 89°W.	4.0	S. 19°W.	4.3	S. 29°W.	4.1	N. 81°W.	7.2	West.	7.3	N. 63°W.	4.8	N. 63°W.	4.6
2,500	S. 77°W.	2.1	S. 55°W.	3.7	S. 88°W.	7.8	N. 94°W.	6.3	N. 72°W.	7.0	N. 82°W.	5.7	S. 18°W.	4.6	S. 24°W.	4.0	N. 84°W.	9.1	N. 87°W.	9.8	N. 80°W.	6.1	N. 69°W.	7.0
3,000	S. 59°W.	2.3	S. 62°W.	4.1		10.2	N. 88°W.	8.0	N. 70°W.	8.8	N. 80°W.	7.5	S. 11°W.	7.3	S. 21°W.	4.2	N. 78°W.	10.7	N. 89°W.	11.3	S. 89°W.	6.2	N. 73°W.	6.3
3,500	S. 76°W.	3.6	S. 81°W.	4.6	S. 87°W.	10.4	N. 84°W.	8.2	N. 74°W.	9.0	N. 74°W.	10.1	S. 9°W.	7.1	S. 15°W.	3.1	N. 73°W.	8.7	S. 89°W.	10.8	N. 87°W.	7.3	N. 78°W.	7.8
4,000	N. 28°W.	5.2	S. 86°W.	5.5	S. 87°W.	10.2	N. 83°W.	8.9	N. 75°W.	8.5	N. 69°W.	11.3	S. 45°E.	8.0	S. 77°W.	1.3	N. 71°W.	8.9	N. 68°W.	10.0	N. 76°W.	6.9	N. 78°W.	8.0
4,500					West.	14.0	N. 85°W.	10.2	N. 44°W.	15.2	N. 66°W.	13.4	S. 45°E.	3.0	N. 6°W.	1.7	N. 68°W.	9.0	N. 55°W.	9.2	N. 76°W.	6.8	N. 84°W.	8.4
5,000									N. 56°W.	14.3	N. 75°W.	15.4					N. 31°W.	13.8	N. 67°W.	9.6	N. 75°W.	7.0	N. 84°W.	

WEATHER IN THE UNITED STATES

GENERAL CONDITIONS

The weather of the month was that appropriate to a normal July; temperature was close to normal in practically all parts of the country; precipitation was irregularly distributed, some areas receiving more than the normal, others less. There were very few destructive storms.—A. J. H.

CYCLONES AND ANTICYCLONES

Twelve low-pressure and eleven high-pressure areas were plotted during the month. None of the lows became important as storms, and there were no indications of hurricanes in adjacent Atlantic waters. The majority of the highs came from the Canadian interior, but were mostly weak.—W. P. Day.

THE WEATHER ELEMENTS

By P. C. DAY, in Charge of Division

PRESSURE AND WINDS

The general distribution of the atmospheric pressure was not unusual for a midsummer month, though anticyclonic conditions were somewhat more pronounced than cyclonic.

In general there were no cyclones that pursued definite courses over extended distances, nor did they cover large areas, though numerous storms of small area prevailed locally in most districts from the Rocky Mountains eastward, and rains were frequent in the Northeastern and Southeastern States, in portions of the Ohio Valley and near-by areas, and in the central Rocky Mountain region.

At the beginning of the month a cyclone of slight importance as to extent of depression and area involved was passing eastward over the Dakotas and Minnesota, attended by generally light precipitation, but its influence appears to have extended far to the southward and heavy rains occurred over much of the central Plains, and some rain fell as far south as Texas and Louisiana. This cyclone quickly disappeared but considerable precipitation resulted therefrom during the 2d over the Great Lakes. On the 3d a barometric depression immediately off the southern New England coast caused local precipitation in that area, and thunderstorms were reported over a considerable area from eastern Texas to the Ohio Valley and southern Appalachian region. On the 5th and 6th low pressure moving from the northern Rocky Mountains toward Lake Superior caused some local heavy rains in near-by areas on those days and its continued eastward movement on the 7th and 8th was attended by rather extensive precipitation from the lower Ohio Valley northeastward to New England, and along the entire Atlantic coast southward to Georgia, continuing locally over the Southeastern States for several days thereafter.

Thunderstorm conditions existed over the middle Plains and to the northeastward on the 12th to 14th, and like conditions prevailed locally over wide areas in the eastern half of the country near the middle of the month, continuing locally along the Atlantic coast until the end of the second decade.

Moderately low pressure over the lower Lakes on the 22d caused general rains from the middle Mississippi Valley northeastward over the Lake region, and thunderstorms were again reported over the Southeastern States.

By the 23d the low pressure had advanced slightly to the eastward and generally rainy conditions existed over the entire Appalachian region, extending later to all Atlantic coast districts.

The latter part of the month had no important cyclonic developments though precipitation of the thunderstorm type occurred over widely scattered areas, becoming somewhat general during the last three days over the interior parts of the country and thence northeastward to New England.

In the far West precipitation was light, as usual, and occurred mainly on the first few days or about the middle of the last decade. In Arizona and adjoining areas the usual summer showers occurred rather frequently in some districts, particularly in the highlands, but in other localities dry conditions existed.

Anticyclones of considerable importance covered the more northern sections on several occasions. That central over the northern Rocky Mountains on the first and moving eastward over the Northern States to the Great Lakes by the 4th and thence southeast to the middle Atlantic coast by the 6th, was probably the most important, as it was attended by the lowest temperatures of the month over extensive areas. Several other anticyclones crossed the country at intervals but they were not important as to their effect upon the general weather conditions.

The average sea-level pressure was above normal over all parts of the United States and also in Canada as far north as observations are obtainable at present, though the excesses were mainly small save in the Rocky Mountain region.

Compared with the preceding month the pressure was higher in all districts of both the United States and Canada, save from the lower Lakes and northern drainage area of the Ohio eastward to near the Atlantic coast. The excesses were considerable over the Rocky Mountain and adjacent areas.

The general distribution of pressure favored southerly winds over the central and southern portions east of the Rocky Mountains and over the Atlantic Coast States as far north as New England, though in the latter area they were frequently southwest and occasionally from the west. Along the northern border from the Rocky Mountains to the upper Lakes they were mainly from northerly points, and similar winds prevailed generally along the Pacific coast.

Local high winds were of frequent occurrence from the Great Plains eastward and they occurred in all portions of the month. Some were of tornadic character, the most important of these occurring in eastern Kansas on the 16th, where some 16 lives were lost and large property damage resulted. Considerable damage occurred also from hail which was of rather frequent occurrence in some of the States.

The details of the more important storms appear in the table at the end of this section.

TEMPERATURE

Day to day changes in temperature were mainly unimportant, rarely exceeding 10° to 15° in 24 hours, and at no time did the temperature vary greatly from the normal for the period save on a few dates. The first few days had some of the warmest weather of the month, notably on the 1st when the highest temperatures of the month were recorded in portions of the

Southeast and Great Lakes region, while from the 2d to the 6th the lowest temperatures of the month were recorded over the greater part of the country. At a few points in the Lake region the minimum temperatures on the 4th were the lowest of record for July. The remaining weeks of the month had average temperatures not far from normal, though there was a general tendency to cooler than normal in the middle and northern portions of the central valleys and eastern districts, with general warmth in the South and far West.

For the month the average temperatures were from 1° to 3° lower than the normal over the middle and upper Mississippi Valley and thence westward to the Great Plains and eastward to the Lake region. Along the Atlantic coast and over portions of the Ohio Valley the averages were mainly less than 2° lower than normal, while west of the Rocky Mountains and in portions of the South the averages were mainly about 1° to 2° higher than normal; a few points in the South, notably Corpus Christi, Tex., and Tampa, Fla., had the highest average July temperatures of record, and the greatest number of days with maximum temperatures 90° or higher of record. Corpus Christi had 20 such days while the average is only 2, and Tampa had 26 with an average of only 14. Chart III of this REVIEW presents the variations from the normal for all parts of the country.

In general the periods of severe heat were of short duration, and in most sections the temperatures were pleasantly comfortable during the entire month. The maximum day temperatures were above 100° however, at sometime during the month in practically all the States save those along the northern border from North Dakota to New England. The highest recorded was 125° at Greenland Ranch, Calif., on the 19th, but 118° occurred in Arizona and Nevada, and 112° in Washington, while 106° was reported from Georgia, a record unsurpassed there in July save on two previous occasions.

Minimum temperatures were below freezing at a few points along the northern border and in the mountain districts. The lowest observed was 22° in the high mountains of California, with 23° in Oregon and 24° in Colorado and Wyoming. The lowest temperatures occurred in practically all parts of the country during the first few days, principally from the 3d to 5th, though they were delayed till the 10th and 11th or 24th in some Southeastern States.

PRECIPITATION

The precipitation varied greatly in fairly near-by areas, a condition not unusual in July but rarely to so pronounced an extent in the States having no great topographic variations.

Generally speaking the amounts received at the regular Weather Bureau stations did not depart greatly from the normal, and the country was fairly evenly divided between sections having totals above normal and those with totals below.

There were rather important excesses in central and southern Georgia, also in North Carolina and Virginia, as well as around the lower lakes, in northern Michigan and northern Louisiana, northwestern Arkansas, southwestern Missouri, and central Illinois. On the other hand the precipitation was materially deficient in Iowa and portions of near-by areas, in the middle Gulf States, portions of the lower Mississippi Valley, Maryland and the District of Columbia, along the South Atlantic coast, and in portions of Texas and New Mexico.

Thunderstorms were unusually frequent in portions of the Southeastern States, and in the Great Lakes region and locally in Texas.

SNOWFALL

No snow was reported during the month from any of the observing stations, though it may have occurred in some of the higher northern mountains.

RELATIVE HUMIDITY

On the whole the percentages of relative humidity were below normal, despite the general coolness over a considerable portion of the country and the excess of precipitation in limited areas. Generally speaking the humidity excesses were confined to areas having more than the normal precipitation, though decided variations from this are noted in some sections. In the Mississippi Valley, where precipitation was mainly deficient, the relative humidity was almost universally below normal and there was a general deficiency in the far West and Northwest where the forest-fire hazard was greatly increased thereby, though no serious outbreaks appear to have occurred.

SEVERE LOCAL STORMS, JULY, 1927

The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau.

Place	Date	Time	Width of path ¹	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
			Yards					
Hahira, Ga.	3				\$150,000	Electrical	Cotton warehouse burned by lightning, destroying 300 bales of cotton; several persons stunned.	Official, U. S. Weather Bureau.
Suffolk, Mont. (8 miles south of)	4	3 p. m.			6,000	Tornado	Buildings damaged; livestock killed; several persons injured.	Do.
Blaine County, Mont.	4	4 p. m.	880-1,700		12,500	Hail	Crops considerably damaged; sheep killed.	Do.
Edgemoor and Rossville sections, S. C.	4	P. m.			10,000	Rain, hail, and wind.	Heavy damage over 3 square miles.	Do.
Lewistown, Mont. (near)	4					Hail and cloud-burst.	Complete loss of some crops.	Do.
Sumter, S. C.	4	P. m.			8,000	Rain, hail, and wind.	Character of damage not reported.	Do.
Kings Mountain, N. C. (near)	5		440			Heavy hail.	Severe damage to cotton and corn, complete loss in places; path 3 miles long.	Do.
Marshall County, Kans.	6	3 p. m.	3 mi.		25,000	do	About 1,000 acres of corn ruined.	Do.
Clyde, Kans. (near)	6	4:30 p. m.				Violent hail and wind.	Damage chiefly to corn and fruit and wheat in shocks.	Do.
Henry County, Iowa	6	7 p. m.	220		80,000	Tornado	Damage chiefly to property other than crops.	Do.
De Kalb., Ogleby, Whiteside, and Rock Island Counties, Ill.	6				85,200	Wind, hail, and rain.	Overhead wires prostrated; many small buildings damaged or wrecked; crops injured; windows broken.	Do.
Fort Wayne, Ind.	6					High wind	Trees, telephone and telegraph lines blown down, small buildings damaged.	Do.
Iowa (southern)	6	P. m.				Wind and hail	Much damage to buildings, crops, and vegetation at various points.	Do.
Westmoreland, Butler, and Lawrence Counties, Pa.	6-7				100,000	Thunderstorm, wind, and rain.	Streets and sewers badly damaged; one house partly destroyed; heavy crop losses.	Do.
Wicomco County, Ind.	7			2	4,000	Thunderstorm	A barn and contents destroyed; another blown over; 2 mules killed; minor damage to other buildings.	Do.
Cooperton, Okla.	7		5 mi.			Hail	Cotton suffered greatly, some fields destroyed; other minor damage.	Do.
Sherman and Howard Counties, Nebr.	8	6 p. m.	3,520		5,500		Considerable damage to grains over path 15 miles long.	Do.
Lyon County, Iowa	8	7:15 p. m.				Tornado	No damage reported.	Do.
Jasper, Minn. (near)	8					Small tornado	Minor property damage.	Do.
Bureau and La Salle Counties, Ill.	9		1,700			Hail	Considerable crop damage over path 10 miles long.	Do.
Vernon County, Wis.	11	3 p. m.	1,700		10,000	Heavy hail	Buildings and crops damaged.	Do.
Juneau, Columbia, Dodge, and Washington Counties, Wis.	11	3-4 p. m.	1,700	1	320,000	Severe squall and probably small tornado.	Extensive crop and property damage over path 30 miles long; 22 persons injured; probably small tornado in central Dodge County.	Do.
Sioux Pass, Mont.	11	4-6 p. m.	3,520			Severe hail	Crops total loss over path 1 mile wide and 12 miles long.	Do.
Iowa (northeastern)	11	P. m.				Hail and wind	Considerable crop and property damage at various points.	Do.
Valparaiso, Ind. (near)	12	2:40-2:45 p. m.	30			Tornadoic wind	Considerable damage to trees, summer cottages, etc.	Do.
St. Croix, Pierce, and Dunn Counties, Wis.	12	6-6:30 p. m.		1	20,000	Severe squall with partially developed tornado.	Damage chiefly to barns, silos, trees, poles; crop loss slight.	Do.
Detroit, Mich., and vicinity.	12	P. m.		2	25,000	Thunderstorm and wind.	Trees and signs blown down; building under construction twisted.	Grand Rapids Press (Mich.).
Iowa (eastern)	12	do				Hail and wind.	Crop damage 50 to 75 per cent in places; buildings and trees also damaged.	Official, U. S. Weather Bureau.
Algonac, Mich., and vicinity.	12	do				Thunderstorm	Storm very destructive to trees and wires.	Do.
Greeley, Colo.	13	4 p. m.	7-14 mi.		1,000,000	Hail	Wheat and sugar-beet crops and windows badly damaged or destroyed over an area of 150 square miles.	Do.
Gentry County, Mo. (southern).	13		4 mi.		30,000	Violent hail and wind.	Extensive crop damage over path 5 miles long.	Do.
Sanilac County, Mich.	13		33-100		50,000	Tornado	A number of buildings blown down, trees uprooted, some crops ruined, over path 15 miles long.	Do.
Ravenna, Nebr.	16	2 a. m.				Hail	Heavy crop damage in scattered areas.	Do.
Wabaunsee and Osage Counties, Kans. Harveyville to Burlingame.	16	4-4:30 p. m.	60	2	100,000	Tornado	Many farm houses and outbuildings demolished; trees uprooted; 12 persons injured; path 12 miles long.	Do.
Morris, Lyon, and Coffey Counties, Kans. Dunlap to Lebo.	16	4:15 p. m.	Few to 300	3	100,000	do	Damage chiefly to farm buildings and crops; extensive destruction in the vicinity of Lebo; path 23 miles long.	Do.
Clark County, Wis. (central).	16	5 p. m.	1,700		54,000	Wind and hail	Much damage to crops by hail; buildings and timber damaged by wind.	Do.
Kansas City, Kans. (south-west suburbs).	16	do	200	4	150,000	Tornado	Greatest damage in South Park, where 20 buildings were completely wrecked; 40 persons injured.	Do.
Chattanooga, Tenn.	16				13,500	Thunderstorm	About 2,000 telephones out of use; streets flooded; automobiles damaged.	Do.
Westchester County, N. Y. (southern).	16					Hail, wind, and rain.	Trees uprooted; garage roofs blown off; roads washed; cellars flooded.	Do.
Leesburg, Ala.	17				5,000	Heavy hail	Cotton and corn ruined in path.	Do.
Iowa (eastern)	18	P. m.				Hail and wind.	Crops total loss in places; some damage to buildings and trees.	Do.
Smackover, Ark.	18	3:30-4 p. m.			60,000	Wind and rain	More than 60 derricks in oil fields blown down.	Shreveport Times (La.).
Alexander, Union, and Jackson Counties, Ill.	19	3-4 p. m.	4 mi.		100,000	Hail	Damage principally to corn and fruit; minor damage to buildings; path 25 miles.	Official, U. S. Weather Bureau.
Glendive, Mont.	19	7:30 p. m.				Tornado	No damage reported.	Do.
Arizona (north-central and southwestern).	19				25,000	Thunderstorms, hail, and wind.	Crops injured; windows and greenhouses damaged at various points.	Do.
Mulberry Grove, Ill.	20				30,000	Hail	Windows broken, roofs pierced; orchards and crops damaged.	Do.
Monroe and La Crosse Counties, Wis.	21	1-3 a. m.	880-5,280		100,000	Heavy hail and rain.	Extensive crop damage; bridges and roads washed.	Do.
Warren County, Ill. (southern).	21	12:30 p. m.	4 mi.		145,000	Heavy hail	Field crops total loss; other property damaged over path 25 miles long.	Do.

¹ "Mi" signifies miles instead of yards.

Place	Date	Time	Width of path	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
			Yards					
Morrellville and Estherville and vicinity, Pa.	21	P. m.				Heavy hail.	Numerous windows broken; considerable damage to growing crops.	Official, U. S. Weather Bureau.
Rock and Walworth Counties, Wis.	21				\$10,000	do.	Tobacco and corn crops severely damaged.	Do.
Hall, N. Y.	23		1,760		20,000	do.	Fruits badly injured; cabbage and peas totally ruined; other crops damaged; path 2½ miles long.	Do.
Nodaway County, Mo.	24	5-6 p. m.			70,000	Severe hail, wind, and rain.	10,000 acres of crops damaged; 2,000 total loss.	Do.
Iowa (western).	24	P. m.				Hail and wind.	Extensive crop losses.	Do.
Emporia, Kans. (near)	25	3 p. m.	12 mi.		50,000	Heavy hail.	Crops devastated over area 12 miles square; 2,500 panes of glass broken.	Do.
Delmar, N. Y., and vicinity.	27	2 p. m.	880		6,000	do.	Considerable damage to truck gardens and greenhouses; path 2½ miles long.	Do.
Pigeon Falls, Wis.	27	3:30 p. m.	1-3 mi.		10,000	Hail and electrical.	Much damage to crops; large barn destroyed by lightning.	Do.
Iowa (northern).	27	P. m.				Hail and wind.	Many thousands of dollars damage to crops and buildings.	Do.
Port Huron, Mich. (near)	27				15,000	Electrical.	2 large barns and contents, including livestock, burned.	Do.
St. Paul and Minneapolis, Minn.	27					Severe wind.	A number of small buildings damaged; telephone service impaired; several persons injured.	Do.
Arcadia, Wis.	28	4 p. m.	880		9,000	High wind.	Damage chiefly to crops.	Do.
Caldwell, Kans., and vicinity.	28	4:40 p. m.				Small tornado.	Many trees torn up; autos damaged; several buildings unroofed; electric service demoralized.	The Wichita Eagle (Kans.).
Monrovia, Kans., to Kansas City, Mo.	28	4:45 p. m.			25,000	Tornado.	4 small houses wrecked, 16 others more or less damaged.	Official, U. S. Weather Bureau.
Libertyville, Iowa (near)	28	6 p. m.				do.	Some buildings wrecked.	Do.
Clinton, N. C. (8 miles south of)	28		3,520			Heavy hail.	Severe damage to crops; pigs and poultry killed; path 8 miles long.	Do.
Iowa (northern).	28	P. m.				Hail and wind.	Crops badly injured; buildings damaged.	Do.
Whitney County, Ind.	28	do.			18,500	Wind.	Character of damage not reported.	Do.
Chicago, Ill. (near)	28	do.		27		Wind squall.	Motor boat wrecked, causing loss of 27 lives.	Do.
Isidore, N. Mex.	30	8-11 p. m.	5 mi.			High wind.	Roofs blown off, trees uprooted; windows broken; windmills blown down.	Do.
Logan, N. Mex.	30	10 p. m.	5 mi.		10,000	Tornadoic wind and hail.	Crops, buildings, and windmills damaged.	Do.
South Dakota (southwestern).	30		2-8 mi.		80,000	Hail and wind.	Crops a total loss in many places; path 50 miles long.	Do.
Crawford County, Kans. (northwest).	31	6 p. m.	2-3 mi.			Heavy hail.	Considerable damage to property over an area several miles square.	Do.
Wuakomis, Okla.	31	7-7:30 p. m.	4 mi.		10,000	Hail.	Considerable damage to property other than crops.	Do.
Massachusetts (southeastern).	31	7:30 p. m.		1	100,000	Thunderstorm and tornadoic wind.	Buildings and trees blown down; communication cut off; much damage by tornadoic wind at Rehoboth.	Do.
Adams County, Wash.	31	P. m.				Wind and hail.	Standing wheat sustained a loss of 25 per cent.	Do.
St. John, Wash. (east of)	31	do.			9,000	do.	More than 350 acres of wheat damaged.	Do.

STORMS AND WEATHER WARNINGS

WASHINGTON FORECAST DISTRICT

The only storm warnings issued during the month were in connection with a disturbance of considerable intensity that moved northwestward from the vicinity of Bermuda and approached the New Jersey coast during the 2d, after which it diminished in intensity and moved northeastward, its center passing near Nantucket during the 3d. Northeast warnings were displayed in advance of this disturbance from Portsmouth, N. H., to Delaware Breakwater, and small-craft warnings south of Delaware Breakwater to Cape Hatteras. The highest wind velocity reported was 48 miles an hour from the northeast at Nantucket. No other station reported a verifying velocity.

Except for small-craft warnings from Cape Hatteras to Delaware Breakwater on the 4th, no storm or small-craft warnings were issued after the 2d.

Frost warnings were issued for the cranberry bogs of New Jersey and Massachusetts and for the interior of northern New England and the northern portion of eastern New York on the 4th. No frost was reported from any regular reporting station, however, the morning of the 5th.—*C. L. Mitchell.*

CHICAGO FORECAST DISTRICT

There was nothing unusual in the weather conditions in the Chicago forecast district during the month of July. The temperature averaged somewhat below the normal, and the rainfall, which was mainly in the form of thunderstorms, was rather irregularly distributed.

Warnings for frost on low ground were issued on July 31 for North Dakota and northwestern Minnesota for the ensuing night, and for the cranberry marshes of Wisconsin for the night following; that is, the night of August 1-2. No frosts occurred on the first night, but they appeared to be general in the cranberry marshes on the second.

Small-craft warnings were ordered for the Great Lakes on a few occasions; and any strong winds that occurred were in the form of local squalls.

The only casualty, as far as known, on the Lakes was the capsizing of the small excursion boat *Favorite* on the afternoon of July 28, close to the near-north shore of Chicago, in which 27 lives were lost. The evidence brought out at the inquiry was that the boat was top-heavy and, as the squall broke, all the passengers rushed to the side of the boat away from the wind and rain; and the boat, being out of balance, toppled over. The squall lasted only five minutes, from 2:24 p. m. to 2:29 p. m. (ninetieth meridian time), and attained a maximum velocity of 49 miles an hour at the station on the municipal pier maintained by the water department of the city of Chicago, about 1 mile from the place where the catastrophe occurred. The wind was light to moderate before and after the squall, the total wind movement being only 15 miles in that hour. Thunderstorms had been predicted not only for Chicago and vicinity, but also for Lake Michigan; but no warnings of any kind had been ordered. The wreck of the *Favorite* was the only casualty which occurred, although a vast number of other vessels were exposed to the squall.

A special wind and weather forecast was issued on July 23 for the route of the Chicago-Mackinac Island cruising race which had its start in Chicago on the after-

noon of that date. The forecast issued at that time covered a period of two days, and additional forecasts were issued the following night and morning and broadcast by radio station KYW.

Advices during the month were wired to the California Fruit Growers' Exchange, Los Angeles, Calif., in advance of the development of heat waves in the Chicago forecast district, in order to guide the exchange in the shipping of fruit to this area.

Fire-weather forecasts were resumed for the State and National forests in Minnesota on July 28.

Special flying forecasts were furnished the national air tour for all the points in and bordering on the Chicago forecast district at which these planes stopped. The tour started from Detroit June 27 and returned July 12. The forecasts, as indicated by a number of the flyers, proved highly satisfactory.—*H. J. Cox.*

NEW ORLEANS FORECAST DISTRICT

Moderate weather conditions prevailed generally during July. No warnings were issued for the west Gulf coast and no general storm occurred.—*I. M. Cline.*

DENVER FORECAST DISTRICT

Frequent disturbances of moderate intensity which advanced eastward from the Rocky Mountain Plateau were attended by the usual summer showers and thunderstorms, especially in the central and northern portions of the district, with an excess of rainfall in Colorado, southeastern Wyoming, and north-central Montana. A marked deficiency in precipitation occurred in most of New Mexico and central and eastern Arizona. While it was cooler than normal over nearly all of the northern portion of the eastern Rocky Mountain slope, the month was generally considerably warmer than the average west of the Continental Divide and in New Mexico.

With the exception of forecasts on the 9th of fresh to brisk westerly winds, and on the 25th of brisk to strong westerly winds, both of which were included in the morning predictions of those dates for Wyoming, no special forecasts or warnings were issued and none was required.—*J. M. Sherier.*

SAN FRANCISCO FORECAST DISTRICT

The more important forecasts and warnings related to the fire-weather situation and to the Smith-Bronte airplane flight. The latter took place on the 14th and 15th of the month and required the issuance of special bulletins on the 14th and on several preceding dates descriptive of weather conditions between the mainland and the islands. Careful attention was paid to these advices by the aviators, especially Mr. Bronte, who was in close touch with the Weather Bureau office at San Francisco for a week before the flight. The bulletins were quite successful and received due acknowledgment from the flyers after the completion of their journey, who testified that their chief dependence was on "dead reckoning." Aside from two sextant observations which gave them some idea of their longitude on the morning of the 15th, they were unable to determine their position from celestial observations, and had they not followed a well-conceived compass course and made very accurate allowance for "drift" their adventure might have ended disastrously. This fact earned their appreciation of the weather bulletins from which alone they derived their drift calculations.

It appears that they were exactly on their course until very near the island of Oahu, when, in doubt as to their latitude and fearful of passing the entire archipelago to the north, they departed from their course, turned southward, and crashed on the island of Molokai. Had they continued straight on, instead of turning to the south, they would have landed safely at Wheeler Field, their objective.

The fire situation in the forests grew slowly but steadily more dangerous, but conditions were not acute over the northern parts of the district until the 22d, when a fragment of the North Pacific high pressure system moved inland, bringing excessively high temperatures and low humidities to Oregon and Washington. This situation was anticipated in warnings issued the day before. Others, similar in type, arising in the North Pacific States, called for like bulletins on the 27th and 31st. Warnings of danger from lightning storms were sent to various California forests on 13 occasions, and the attempt at localization achieved some degree of success. On one occasion, viz, the 28th, more than 100 fires were started by lightning in the Klamath, Trinity, Shasta, and Lassen national forests within 48 hours after issuance of the predictions. Thunderstorm warnings were also incorporated on numerous occasions in the State forecasts for Washington, Oregon, Idaho, and Nevada.—*Thomas R. Reed.*

RIVERS AND FLOODS

By R. E. SPENCER

The great flood in the Mississippi River finally terminated on July 14, 1927, with the falling of the water below flood stage at Baton Rouge, La.; and by the end of the month the entire lower river was well within the bankful stage. As noted in the special flood bulletin of the New Orleans Weather Bureau office of August 1, 1927, however, considerable areas of swamp bottoms and between 30,000 and 35,000 acres of agricultural land were still inundated. As the recession of water from these areas will depend almost wholly upon absorption and evaporation, it will of course take place very slowly.

The annual rise in the Columbia River, report on which was deferred from the June issue of this REVIEW, occurred substantially as predicted in the Portland, Oreg., snowfall bulletin of April, 1927. It was stated in that bulletin that owing to the snowfall excess in the Columbia drainage basin the crest of the rise would, with the prevalence of normal temperature, be later than and above the average. Relatively cool weather prevailed well into June, and the date of the crest at Portland was 9 days later and 2.9 feet higher than the average. Warnings of the approach of the flood received wide and effective distribution, so that practically no movable property was lost, farmers generally refrained from planting lands that were likely to be flooded, and suspension of business was reduced to a minimum. Incomplete reports of losses due to this flood give the following figures:

Tangible property.....	\$17, 041
Matured crops.....	33, 125
Prospective crops.....	80, 600
Livestock and other movable property.....	500
Suspension of business.....	109, 900
	<hr/> 241, 166

Property valued at \$152,650 was reported saved by the warnings; but the official in charge of the Weather Bureau office at Portland reports that "probably the greatest benefit of the river service this year was in preventing

undue alarm." The excess of snow in the mountains of the basin gave rise to a number of amateur prophecies and widespread public expectation of extreme high water, and the persistent denial by the Weather Bureau of this probability undoubtedly prevented the expenditure of large sums of money that would otherwise have been spent for protective measures.

Other floods during July were in all cases of little magnitude and without damage. The report on the June rises in the St. Louis district is again deferred.

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC DRAINAGE					
Santee:	<i>Feet</i>			<i>Feet</i>	
Rimini, S. C.-----	12	20	25	13.3	July 23-24.
Ferguson, S. C.-----	12	23	28	12.6	July 26.
Saluda: Chappells, S. C.-----	14	19	19	14.0	July 19.
MISSISSIPPI DRAINAGE					
Mississippi:					
Vicksburg, Miss.-----	45	(1)	11	58.7	May 4.
Natchez, Miss.-----	40	(1)	10	56.5	May 1 and 4.
Angola, La.-----	45	(1)	13	57.5	May 15-17.
Baton Rouge, La.-----	35	(1)	14	47.8	May 15.
Donaldsonville, La.-----	28	(1)	8	37.1	May 15-17.
Illinois:					
Havana, Ill.-----	14	(1)	4	22.05	June 8.
Beardstown, Ill.-----	14	(1)	8	25.2	Apr. 26.
Pearl, Ill.-----	12	(1)	6	22.7	Apr. 26-27.
Missouri: Blair, Nebr.-----	16	(1)	3	16.8	June 26.
Osage: Osceola, Mo.-----	20	23	24	21.3	July 23.
Arkansas:					
Dodge City, Kans.-----	5	24	24	5.0	July 24.
Yancopin, Ark.-----	29	(1)	8	48.5	Apr. 20.
Cache: Patterson, Ark.-----	9	(1)	3	9.7	June 29-30.
Yazoo: Yazoo City, Miss.-----	25	(1)	12	37.4	May 5.
Sulphur: Ringo Crossing, Tex.-----	20	18	20	21.6	July 20.
WEST GULF DRAINAGE					
Trinity: Dallas, Tex.-----	25	16	17	28.6	July 17.
Rio Grande:					
San Benito, Tex.-----	23	(1)	(?)	24.6	June 25.
Brownsville, Tex.-----	18	(1)	(?)	18.4	June 28.
PACIFIC DRAINAGE					
Colorado: Parker, Ariz.-----	7	(1)	23	11.3	July 5 and 6.
Columbia:					
Marcus, Wash.-----	24	(1)	27	32.2	June 19-20.
Vancouver, Wash.-----	15	(1)	16	23.9	June 18-20.
Pend O'Reille: Newport, Wash.-----	16	(1)	13	23.7	June 22-23.
Williamette: Portland, Oreg.-----	15	(1)	14	23.0	June 19-20.

¹ Continued from last month.

² Below flood stage at 8 a. m., July 1, 1927.

MEAN LAKE LEVELS DURING JULY, 1927

By UNITED STATES LAKE SURVEY

[Detroit, Mich., August 4, 1927]

The following data are reported in the "Notice to Mariners" of the above date:

Data	Lakes ¹			
	Superior	Michigan and Huron	Erie	Ontario
Mean level during July, 1927:				
Above mean sea level at New York.....	602.69	579.55	572.16	246.01
Above or below—				
Mean stage of June, 1927.....	+0.36	+0.12	-0.04	-0.10
Mean stage of July, 1926.....	+1.83	+1.01	+0.96	+0.81
Average stage for July last 10 years.....	+0.62	-0.84	-0.32	-0.34
Highest recorded July stage.....	-1.13	-4.03	-2.25	-2.71
Lowest recorded July stage.....	+1.83	+1.01	+1.04	+1.42
Average departure (since 1800) of the July level from the June level.....	+0.21	+0.07	-0.04	-0.04

¹ Lake St. Clair's level: July, 1927, 574.99 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, JULY, 1927

By J. B. KINCER

General summary.—Higher temperatures in Central and Northern States the first part of the month promoted better growth of warm-weather crops and mostly dry conditions, or only light to moderate showers, permitted generally good advance of field operations. Several days of abnormally warm weather east of the Great Plains were of especial benefit to the corn crop, but were rather unfavorable for winter grains in some central-northern districts. Rain was needed in northern areas from the upper Mississippi Valley eastward and locally elsewhere. In the Southeast drier weather favored cultivation, but in parts of the western Gulf area rather frequent showers hindered outdoor operations and there were some complaints of grassy fields. Moisture was still deficient from the upper Mississippi Valley eastward during the second decade, but the weather was favorable for harvesting and threshing in the grain area during most of the period.

During the latter part of the second decade rather widespread showers were timely and beneficial in most sections and the temperatures were favorable for rapid advance of most crops, with moisture conditions generally satisfactory, except for rather limited areas. Dry, sunny weather was again desired in the Southeast, but the warmer weather was especially favorable in the Northeast. In far western States more moisture was needed in some portions, but, in general, conditions were favorable. Rather cool weather during the last decade retarded the growth of warm-weather crops somewhat, but showers were helpful in previously dry sections, although at the close of the month it had again become droughty in the Lake region.

Small grains.—Winter wheat harvest made generally excellent advance during the first decade with cutting advancing at the close of the period north to Pennsylvania, southern Michigan, and northern Nebraska. Threshing advanced satisfactorily in the southern portion of the belt. Showers made conditions somewhat less favorable for cutting winter wheat during the second decade, but progress was mostly good and threshing made generally satisfactory advance. There was also some interruption to threshing during the last decade, but harvest was largely completed, except in the later districts. In the Spring Wheat Belt weather conditions continued favorable during the first decade and the crop made rapid advance, but rain was needed in some parts of North Dakota and Montana. Early spring wheat was heading to the northern part of the belt with stands and color satisfactory; there were reports of black rust, but no indications of general serious damage. The weather continued generally favorable during the remainder of the month and good advance was reported. There was some local cutting by the close of the month and the crop was filling and ripening very satisfactorily. Except for extensive reports of black stem rust in southern Minnesota, this disease was not widespread and much of the crop at the close of the month was believed to be too far advanced for material harm.

Corn.—Corn made better advance during the first decade and cultivation was favored the first part of the month by mostly fair weather. Progress of the crop was fair to very good in most portions of the belt, though

cool weather the middle of the period was detrimental for best growth. Rain was needed in most of Iowa and would have been beneficial over considerable portions of the trans-Mississippi States. Numerous showers and generally favorable temperature conditions were helpful for corn during the second decade, though moisture was insufficient in some interior valley sections and locally in the Great Plains. In Iowa progress was mostly fair to good with the early crop in the western third tasseling at about the normal date, and advance was very good to excellent in the Great Plains and lower Missouri Valley. During the last decade temperatures were rather too low for best growth of corn from the Ohio and central Mississippi Valleys northward, but the crop made fair to good progress generally. Showers were helpful in many parts of the belt and, while rain was needed in more or less limited areas, there was no widespread need of soil moisture. While corn showed material improvement during the month it was still late and uneven at the close with indications that some of the late crop could make only fodder.

Cotton.—Temperatures in the Cotton Belt were rather moderate, except that nights in the eastern portion were rather too cool for best growth during the first decade. Moisture was generally favorable, except that further rains in the East were unfavorable with complaints of grassy fields and rank growth in some places. Progress of the crop ranged from fair to excellent in the Carolinas and fair to very good in the central portion. Fair to excellent progress was noted in western areas, but there were complaints of increased weevil activity, shedding, and poor fruiting locally.

During the second decade mostly moderate temperatures and rainfall prevailed, and in the Atlantic Coast States the growth of cotton was very good to excellent, but weevil activity increased generally and cultivation was hindered locally. In the central portion progress was satisfactory and in the northwestern section very good advance was made. Progress and condition were

mostly fair to very good in the Southwest, though there was some complaint of rank growth and grassy fields; fruiting was progressing well and picking advanced favorably in the South. Conditions continued moderate and favorable the latter part of the month and in the East good to excellent growth was made, although there were complaints of increased weevil activity; while this condition was noted also in central sections, generally fair to excellent advance was made. Progress in the Northwest depended generally on insect infestation, but in the Southwest the weather was mostly favorable, though the condition and advance of the crop was spotted and averaged only fairly good. Picking progressed well the latter part of the month in the South.

Ranges, pastures, and livestock.—Pastures in the East continued in mostly good to excellent condition throughout the month, although there were some local complaints of dryness in the middle Atlantic area and in the Lake region. Ranges continued dry in southern New Mexico and some areas of the Great Basin, and locally elsewhere. Outside of the local dry areas, ranges were in mostly satisfactory condition in much of the great western grazing area and livestock were good to excellent generally. Showers were detrimental to haying locally and there was some damage to cut hay and alfalfa, but this work, in general, was favored by good weather.

Miscellaneous crops.—Potatoes were in mostly satisfactory condition during the month, except that more moisture was needed in the Lake region at the close. Truck crops were favored generally and were doing well. Tobacco did well in the Southeast with curing advancing; there were some complaints of irregular advance in Kentucky, due to dryness, but elsewhere the crop progressed satisfactorily. Sugar cane made good to excellent advance and sugar beets did well generally. There were complaints of heavy drop of apples in some north-eastern sections the first part of the month and the condition of fruit in general was rather poor in central and central-northern areas. Citrus fruits did well in Florida.

WEATHER ON THE ATLANTIC AND PACIFIC OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

As shown on the Pilot Chart, July is normally the quietest month over the North Atlantic Ocean, and the current month is no exception to the general rule. According to reports received up to date, the greatest number of gales occurred in the 5° square between the forty-fifth and fiftieth parallels and the fifteenth and twentieth meridians, where they were observed on four days. The region west of the thirty-fifth meridian was apparently free from heavy weather, with the exception of one day with moderate gales over the mid-western section of the steamer lanes, and disturbances of a local nature in southern waters that are described in the notes at the end of this article. Up to the present writing, September 1, 21 storm reports for July have been received, and of these only four show a maximum force of wind as high as 9. Due to the rarity of cyclonic disturbances no charts were drawn.

Fog was unusually prevalent over the greater part of the ocean, and especially off the coast of New England and over the Grand Banks, where it was observed on 23 and 20 days, respectively; it was reported on from 8 to 11 days over the middle section of the steamer lanes, and from 1 to 8 days off the coast of Europe.

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TABLE 1.—Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (75th meridian), North Atlantic Ocean, July, 1927

Stations	Average pressure	Departure ¹	High-est	Date	Low-est	Date
	Inches	Inch	Inches		Inches	
Belle Isle, Newfoundland.....	29.94	+0.07	30.36	22d....	29.42	5th.
Halifax, Nova Scotia.....	30.05	+0.13	30.36	22d....	29.68	4th.
Nantucket.....	30.01	+0.03	30.24	21st ² ..	29.72	3d.
Hatteras.....	30.05	+0.03	30.20	6th ² ..	29.80	2d.
Key West.....	30.05	+0.04	30.14	11th ² ..	29.96	1st.
New Orleans.....	30.05	+0.05	30.16	25th....	29.92	2d.
Swan Island.....	29.91	-0.01	29.98	27th....	29.82	14th.
Turks Island.....	30.10	+0.09	30.18	26th ² ..	29.98	18th.
Bermuda.....	30.25	+0.14	30.40	10th ² ..	29.78	1st.
Horta, Azores.....	30.23	-0.04	30.48	10th....	29.96	18th.
Lerwick, Shetland Islands.....	29.88	+0.08	30.29	16th....	29.40	28th.
Valencia, Ireland.....	29.86	-0.12	30.33	15th....	29.49	27th.
London.....	29.89	-0.09	30.23	19th....	29.33	1st.

¹ From normals shown on Hydrographic Office Pilot Chart based on observations at Greenwich mean noon, or 7 a. m., 75th meridian.

² And on other dates.

On the 2d a disturbance of moderate intensity was central near 46° N., 30° W.; this moved slowly eastward, and on the 6th the center was off the west coast of Ireland. During this period, moderate gales were reported by vessels near the center of the Low, which was of limited extent.

On the 18th a comparatively slight disturbance was central near 48° N., 20° W., as shown by report in table.

From the 25th to 29th considerable cyclonic activity prevailed over the middle and eastern sections of the steamer lanes that reached its greatest intensity on the 28th and 29th, with moderate gales on these dates along the 50th parallel, between the 20th and 40th meridians.

On the 29th gales were reported along the American coast between Jacksonville and Hatteras, as shown by report in table from the British S. S. *Comanche*.

NOTES

Am. S. S. *Gulf Trader*; Capt. N. Borgersen; observer, J. N. Converse. From Philadelphia to Port Arthur: July 4, 2:15 to 3:30 a. m. approximate position 33° N., 75° 30' W. Passed through electrical storm of unusual severity. A steady cross fire of chain and ball lightning with steady crash of thunder. SW. wind of hurricane force for a short time. Very heavy rain.

Am. S. S. *Steel Mariner*; Capt. H. W. Doyle; observer, H. Hendrickson. From Colon to Portsmouth, N. H.: July 10-12, from Colon to Navassa Island, off west coast of Haiti, experienced strong wind, increasing to fresh gale at times, with a steady barometer.

Am. S. S. *Gulf Prince*; Capt. Chas. G. Carlsen; observer, 2d mate. From Beverly, Mass., to Port Arthur: July 8, 11:45 to 11:55 a. m., observed a large waterspout 6 miles SE. of Fowey Rocks. Spout was moving north.

Am. S. S. *West Celeron*; Capt. E. P. White, jr.; observer, R. H. Perry. From Marseille to Galveston: July 6 in 25° 50' N., 76° 30' W., sighted waterspouts. Heavy rolls of Nimbus clouds and heavy rain squalls. Upper clouds moving toward SW. and lower toward NE. Barometer 29.95 inches. Temperature of air 79°.

French S. S. *De La Salle*; Capt. A. Sylvestre; observer, M. Guillon. From Habana to New Orleans: On July 27 observed two waterspouts. The first at 7 p. m. was broken rapidly. The second from 7:18 to 7:27 p. m. at the same spot, inclination from the clouds about 45°. Ship's position, 27° 56' N., 88° W. Approximate position of spout: Distance from ship 7 miles, bearing N. 30° E, true. Temperature of air 86°. Wind ESE., 2. Clouds from which spout came, Cu. Nb. Direction of lower clouds, W.

OCEAN GALES AND STORMS, JULY, 1927

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN													
Binnendijk, Du. S. S.	Newport News.	Rotterdam	47 05 N.	27 45 W.	July 2	4a., 3d	July 3	Inches 29.53	W	NW., 8	NW	NW., 8	Steady.
Bellenline, Am. S. S.	Rotterdam	New York	49 30 N.	14 10 W.	3	3d	6	29.17	S	W., 7	NE	NW., 8	SW.-W.
Houatonic, Br. S. S.	South Shields	Tampico	49 32 N.	6 12 W.	3	Mdt., 3d	6	29.46	SE	S., 8	NNW	S., 8	SSE.-SSW.
Bristol City, Br. S. S.	Fowey, England.	Philadelphia	49 10 N.	17 37 W.	5	9a., 5th	6	29.45	W	W., 7	W	W., 8	WSW.-W.
Ontario, Fr. S. S.	Dunkirk	New York	49 27 N.	11 44 W.	6	9a., 6th	7	29.42	SW	SW., 7	NW	NW., 9	SW.-W.-NW.
West Eldara, Am. S. S.	New York	Antwerp	48 35 N.	18 55 W.	9	1a., 9th	9	30.18	N	N., 8	N	N., 8	Steady.
Burgerdijk, Du. S. S.	do	Rotterdam	48 30 N.	19 51 W.	17	4a., 18th	18	29.46	E	E., 8	ESE	E., 8	E.-ESE.
West Eldara, Am. S. S.	Antwerp	New York	50 20 N.	30 00 W.	24	4a., 25th	28	29.57	W	W., 8	NNW	NW., 8	SW.-W.-NW.
United States, Dan. S. S.	Oslo	do	51 46 N.	34 10 W.	27	2a., 28th	28	29.39	SE	NW., 8	NW	NW., 9	SW.-W.-NW.
Arkansas, Dan. S. S.	Newcastle	Boston	52 15 N.	29 08 W.	28	2p., 28th	29	29.30	SW	SW., 7	NNE	—, 9	SE-SW.-NW.
San Nazario, Br. S. S.	The Tyne	Canal Zone	51 31 N.	19 23 W.	28	2p., 28th	30	29.25	SE	SW., 6	WNW	SW., 9	SE-SW.-NW.
Comanche, Br. S. S.	Baytown	London	30 54 N.	79 12 W.	29	4a., 29th	29	30.10	SSW	Var. 5	Var	NNW., 8	Steady.
Hellig Olav, Dan. S. S.	New York	Christian-sand.	51 35 N.	34 56 W.	28	4a., 29th	29	29.64	NW	NW., 8	NW	NW., 8	Steady.
NORTH PACIFIC OCEAN													
W. S. Miller, Am. S. S.	San Pedro	Balboa	20 08 N.	106 41 W.	July 1	2p., 1st.	July 1	29.56	E	ESE., 11	SSE	ESE., 11	ESE.-SE.
Steel Mariner, Am. S. S.	do	do	19 37 N.	105 53 W.	1	1p., 1st.	1	29.76	SE	SSE., 8	S	SSE., 8	NE.-S.
West Chopaka, Am. S. S.	San Francisco.	Shanghai	50 00 N.	176 00 W.	4	1a., 4th	5	29.18	SE	SE., 8	S	SE., 8	SE.-S.
Eelbeck, Am. S. S.	Honolulu	Balboa	16 40 N.	112 30 W.	5	1a., 6th	7	29.70	SSW	W., 5	SSW	SSW., 9	WNW-SSW.
Patrick Henry, Am. S. S.	do	Manila	15 10 N.	131 50 E.	13	2a., 14th	15	29.29	S	E., 5	WSW	WNW., 8	Variable.
Dewey, Am. S. S.	Hong Kong	San Francisco.	25 22 N.	119 41 E.	16	2a., 17th	17	29.24	N	NNE., 10	NE	NNE., 10	NNE.-N.
SOUTH PACIFIC OCEAN													
Tahiti, Br. S. S.	San Francisco.	Sydney	34 35 S.	154 29 E.	8	4p., 8th	9	29.70	SW	NW., 4	—	SW., 8	NW.-SW.
Pleiedon, Br. S. S.	San Pedro	Auckland	30 05 S.	178 20 W.	10	—, 12th	14	29.54	NW	WSW., 8	SW	WSW., 8	Do.
West Nivaria, Am. S. S.	New Zealand.	Honolulu	New Plymouth, N.Z.	10	8a., 11th	14	28.96	NE	S., 6	SW	W., 10	W., 10	S.-W.
INDIAN OCEAN ¹													
Roepat, Du. S. S.	Du. East Indies.	Suez	8 51 N.	52 20 E.	3	4a., 4th	4	29.72	SW	SW., —	SW	SW., 10	Steady.
Zurichmoor, Br. S. S.	Karachi	Port Said	18 50 N.	59 45 E.	5	8a., 5th	7	29.55	SW	SW., 6	SSW	SW., 8	Do.
Atlanta City, Am. S. S.	Penang	Aden	7 20 N.	57 30 E.	12	7a., 13th	13	29.79	SW	SW., 8	SW	SW., 8	Do.
SOUTH ATLANTIC OCEAN													
Gedania, Dan. S. S.	Talara	Campana	35 05 S.	55 17 W.	5	2p., 5th	7	—	E	WNW., 8	SW	WNW., 8	WNW.-SW.
Saint Dunstan, Br. S. S.	Cardiff	River Plate	31 58 S.	51 02 W.	6	—, 7th	8	30.20	W	W., 9	SW	W., 9	WNW.-WSW.
Chincha, Am. S. S.	Durban	Rio de Janeiro.	26 48 S.	27 13 W.	13	10p., 16th	16	30.18	SE	ENE., 4	E	ESE., 8	—
Clearwater, Am. S. S. (late report for June).	Brazil.	New Orleans.	31 51 S. ²	50 23 W. ²	June 10.	4p., 11th	June 13.	29.15	N	SW., 12	SSW	SW., 12	—

¹ Reports of southwest monsoon.² Near.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

Following upon the abnormal activity of the Aleutian Low for the season during the previous month, July witnessed its practical disappearance and a settling of pressure into stable summer conditions over the eastern part of the North Pacific Ocean. Apparently throughout all this area pressures were slightly above normal. The anticyclone west of the United States was firmly established during July, and remained undisturbed from intrusion by any middle latitude cyclones. This quiet state of atmosphere, with prevailing high-pressure conditions, extended across the ocean to the coast of Japan; hence no gales of consequence occurred over the main body of water, only one or two instances of winds attaining force 8 having been reported outside of lower middle latitudes and the tropics.

The following table of pressures at several island and coast stations in west longitudes gives an idea of the general conditions in this region:

TABLE 1.—Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean, July, 1927

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	Inch	Inches		Inches	
St. Paul ¹	29.93	+0.08	30.20	28th	29.58	6th.
Kodiak ^{1,2}	29.99	+0.03	30.24	1st.	29.60	21st.
Midway Island ¹	30.10	+0.02	30.28	12th.	29.90	25th.
Honolulu ²	30.05	+0.03	30.11	12th.	29.95	21st.
Juneau ²	30.13	+0.08	30.34	21st.	29.88	3d.
Tatoosh Island ^{1,2}	30.11	+0.04	30.31	9th.	29.84	23d.
San Francisco ^{1,2}	29.98	+0.03	30.17	8th.	29.84	14th.
San Diego ^{1,2}	29.94	+0.05	30.04	8th.	29.85	23d.

¹ P. m. observations only.
² 28 days.

¹ A. m. and p. m. observations.
² Corrected to 24-hour mean.

In lower latitudes the general serenity was interrupted only by two typhoons in the Far East, and by two or three brief-lived cyclones off the Mexican west coast. The subjoined article by Rev. José Coronas, S. J., of the Manila Observatory, describes the typhoons. The report of the American steamer *Patrick Henry*, mentioned in the article, will be found with others in the accompanying gale and storm table, as also the report of the American steamer *Dewey*, which rode out the same typhoon while in Haitian Strait, near the northern entrance to Taiwan Channel.

The first disturbance of the month off the Mexican coast occurred on July 1. This storm was very severe within narrow limits, the American tank steamer *W. S. Miller*, in 20° 08' N., 106° 41' W., at 2 p. m., reporting an ESE. gale of force 11, with blinding rain, and a minimum pressure of 29.56 inches, after which the wind rapidly lessened. The American steamer *Steel Mariner*, a short distance to the southeastward, with a maximum wind force of 8, remarked upon the abruptness with which the gale came on.

On July 5 the American steamer *Eelbeck*, southward bound, ran into the southwest quadrant of a cyclone near 17° N., 114° W., the wind being northwest. At 1 a. m. of the 6th, in 16° 40' N., 112° 30' W., the wind changed to west, force 5, pressure 29.70, which was the lowest observed; at 2 a. m. the wind changed to south, force 7, and at 3 a. m. to south-southwest, force 9. The wind thereafter continued from south-southwest, force 8, until shortly after 6 a. m., when it moderated. The cyclone was evidently proceeding in a west-northwesterly direction seaward, whereas the storm of the 1st continued closely hugging the coast.

A third cyclone, of unknown intensity, was reported on the 28th south of the Gulf of Tehuantepec, moving eastward.

Aside from the cyclonic gales, the only other high wind reported from this general region was that experienced at La Libertad, Salvador, on the 23d, by the Panaman motor ship *City of San Francisco*, when a "chubasco came up from ESE., with force up to 8, continuing from 9:50 to 10:15 p. m."

The observer at Honolulu reported the greatest average wind movement on record for the month of July, it being 11.1 miles. The maximum velocity, however, was only 32 miles from the east, on the 26th. The prevailing direction was east.

One of the most important meteorological features of the month was the frequent fog which banked heavily over the whole northern part of the ocean, and extended in lesser degree down the Asiatic coast to the thirtieth parallel, and down the American coast nearly to the twentieth. The Japanese steamer *Hoyeisan Maru*, Yokohama to San Francisco, reported "always dense foggy" from July 3, in 36° N., 142° 11' E., to July 15, in 45° 23' N., 143° 50' W. The thickest and most frequent fog was reported from Bering Sea. At St. Paul—data taken from a. m. and p. m. observations only—it occurred on 25 days, which is 80 per cent of the number for the month. Along the upper steamer routes west of 170° W., in which region June and July are the months of maximum occurrence, fog was next most frequent, occurring on 20 to 45 per cent of the days.

Tropical cyclone of June 14-18, 1927, off the west Mexican coast.—Data which were received by the Weather Bureau too late for inclusion in the North Pacific weather report for June, indicate that a small tropical cyclone of moderate violence passed up the west coast of Mexico about the middle of the month. According to the Mexican Weather Maps, the cyclone was first observed as a depression centered near 14° N., 100° W., on June 14. It moved northwestward and disappeared apparently in the Gulf of California on the 18th. In the following report to the Hydrographic Office, the American tanker *Robert E. Hopkins*, Balboa to San Pedro, furnished the only vessel account of the disturbance yet received:

June 16, 1927 (noon position, lat. 17° 56' N., long. 103° 08' W.) at 11 a. m., experience fresh NE. wind, barometer 29.58, and wind increasing, with swell coming in all directions. By noon wind force was 9 with heavy, confused sea. Vessel was hove to. By 0:45 p. m. wind calmed down, then at 1:15 p. m. wind came from SW., force 9, heavy sea; lasted half hour, when it moderated to a gentle breeze by 6 p. m., but still having moderately heavy SSW. swell.

TYPHOONS AND DEPRESSIONS

TWO TYPHOONS IN THE FAR EAST DURING JULY, 1927

By Rev. JOSÉ CORONAS, S. J.

[Weather Bureau, Manila, P. I.]

There have been only two typhoons over the Far East during this month of July—one over Formosa and another over the northern part of the Philippines.

The Formosa typhoon, July 14 to 19.—According to weather reports from the steamer *Patrick Henry*, this typhoon existed already in the early morning of July 14, near 15° latitude N., between 131° and 132° longitude E. It moved WNW. toward Formosa. At 8 a. m. of the 15th the steamer *Tjikandi* met the center of this typhoon about 250 miles to the E. by S. of Balintang Channel. The steamer received a most severe buffeting and had to turn back to Hong Kong for repairs.

The center traversed the southern part of Formosa in the evening of July 16, and entered the China coast very near to the south of Amoy in the morning of July 17.

The position of the center at 6 a. m. of July 14 to 17 was as follows:

July 14, 6 a. m., 131° 30' longitude E., 15° 00' latitude N.
15, 6 a. m., 127° longitude E., 18° 15' latitude N.
16, 6 a. m., 123° 50' longitude E., 20° 40' latitude N.
17, 6 a. m., 118° 30' longitude E., 23° 50' latitude N.

The typhoon of Aparri and Hong Kong, July 19 to 27.—This typhoon was probably forming from July 19 to 21 over the Pacific about 250 miles to the east of Luzon between 126° and 127° longitude E., 16° and 17° latitude N. It moved to WNW. and passed very near to Aparri during the night of July 22 to 23. Observations received from our stations nearest to the center do not give any sign of a strong typhoon. Yet it increased in intensity in the China Sea, and passed over Pratas at 1 p. m. of

the 24th, and then close to Hong Kong at 3 a. m. of the 25th as a strong and much developed typhoon. The lowest barometric minimum at Hong Kong was 735.21 mm. (28.946 inches), and the wind reached a maximum squall velocity of 72 miles per hour.

The steamer *President Madison* was very much involved in this typhoon close to the China coast to the ENE. of Hong Kong with a barometric minimum as low as 731.60 mm. (28.80 inches) at 2 a. m. of the 25th and hurricane winds from the NE. quadrant.

The approximate position of the center of this typhoon at 6 a. m. of July 23, 24, and 25 was as follows:

July 23, 6 a. m., 120° 30' longitude E., 19° 15' latitude N.
24, 6 a. m., 118° longitude E. 20° 35' latitude N.
25, 6 a. m., 113° 20' longitude E. 23° latitude N.

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, July, 1927

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
Alabama	80.8	+0.7	Eufaula	105	12	Riverton	55	5	4.04	-1.41	Spring Hill	10.63	Florence	1.03
Arizona	82.0	+1.0	3 stations	118	17	Bright Angel Ranger Station	31	17	1.83	-0.55	Tombstone	6.86	Canon	0.00
Arkansas	79.6	-0.4	Amity	104	11	2 stations	49	14	4.25	+0.43	Pindall	8.63	Magnolia	0.58
California	73.5	+1.0	Greenland Ranch	125	19	Blue Ridge	52	24	6.42	-0.02	Yreka	1.41	154 stations	0.00
Colorado	65.8	-0.5	4 stations	102	16	Nast	24	3	2.74	+0.34	Holly	9.64	Norwood	0.15
Florida	81.9	+0.7	3 stations	102	1	Coral Gables	61	10	6.99	-0.23	Niceville	13.63	Coral Gables	1.10
Georgia	79.8	0.0	Eastman	106	1	Blue Ridge	52	24	6.42	+0.71	Hazlehurst	13.13	Fort Gaines	1.46
Idaho	68.7	+0.3	5 stations	107	17	Obsidian	26	5	0.23	-0.38	Irwin	1.67	15 stations	0.00
Illinois	74.5	-1.5	Mount Carmel	100	1	Mount Carroll	44	8	3.26	-0.05	Salem	8.31	Oregon	0.13
Indiana	74.0	-1.3	Greencastle	101	28	4 stations	45	14	3.41	+0.01	Marengo	6.99	Columbus	1.81
Iowa	72.9	-0.9	2 stations	102	11	2 stations	45	13	1.96	-1.80	Mount Ayr	4.80	Webster City	0.09
Kansas	77.2	-1.1	3 stations	106	19	3 stations	49	13	3.71	+0.24	Elkhart	9.86	Bison	0.79
Kentucky	75.7	-1.2	Bowling Green	101	28	Farmers	45	6	3.71	-0.46	Maysville	6.72	Williamstown	1.81
Louisiana	82.2	+0.6	Dodson	105	18	Lake Providence	58	14	4.94	-1.28	Crowley	11.28	Natchitoches	1.93
Maryland-Delaware	74.2	-1.0	2 stations	100	13	Oakland, Md.	39	5	3.82	-0.51	Aberdeen, Md.	7.55	Baltimore, Md.	1.41
Michigan	67.3	-1.3	Houghton Lake	101	1	2 stations	51	14	3.09	+0.16	Painesdale	9.69	South Haven (No. 1)	0.73
Minnesota	66.4	-2.9	2 stations	98	27	Meadow Lands	29	5	2.72	-0.84	Cloquet	5.95	Mankato	0.54
Mississippi	81.7	+1.0	Utica	104	18	2 stations	57	14	3.45	-1.40	Waynesboro	10.96	Greenville	0.51
Missouri	75.8	-1.6	Sikeston	101	10	2 stations	48	14	4.13	+0.08	Aurora	10.95	Concordia	0.88
Montana	65.5	-0.8	Bridge	104	9	Conway's Ranch	27	16	1.68	+0.06	Baker	5.17	Libby	0.04
Nebraska	73.4	-1.2	Alma	106	6	Fort Robinson	35	25	1.94	-1.46	Table Rock	5.91	North Platte	0.43
Nevada	74.5	+0.5	Clay City	118	29	Rye Patch	27	5	0.26	-0.11	Sharp	1.84	6 stations	0.00
New England	68.8	-0.2	Fitchburg, Mass.	97	13	Garfield, Vt.	34	6	4.31	+0.55	Hardwick, Mass.	8.00	Block Island, R. I.	2.04
New Jersey	72.7	-1.0	2 stations	99	13	Charlottesville	36	6	6.06	+1.27	Verona	9.34	Phillipsburg	2.95
New Mexico	72.8	+0.3	2 stations	108	21	Diener	30	1	2.76	+0.14	Cloudercroft	9.52	Orogrande	0.16
New York	68.6	-1.0	2 stations	99	13	Allegany State Park	31	5	4.88	+0.96	Mount Vernon	9.57	Voorheesville	1.86
North Carolina	75.5	-0.6	Weldon	102	29	Banners Elk	43	24	5.40	-0.65	Greensboro	10.54	Terra Cota	1.43
North Dakota	65.4	-2.1	Hettinger	97	27	New England	28	2	2.85	+0.24	Dunn Center	6.99	Mayville	0.70
Ohio	72.6	-0.9	3 stations	99	1	Bangorville	39	4	4.54	+0.76	Lancaster	8.48	Wiloughby	1.32
Oklahoma	80.0	-0.9	4 stations	108	17	3 stations	51	12	5.17	+2.09	Tishomingo	14.23	Chattanooga	1.00
Oregon	66.8	+0.3	2 stations	110	23	Fremont	23	4	0.17	-0.34	Crater Lake	1.21	20 stations	0.00
Pennsylvania	71.7	-0.2	Lebanon	100	13	West Bingham	29	5	4.97	+0.62	Lykens	11.82	Williamsport	1.81
South Carolina	78.3	-1.4	Garnett	104	1	Hogback Mountain	55	11	6.38	+0.47	Pinopolis	13.78	Hogback Mountain	2.65
South Dakota	69.2	-2.6	Wagner	102	18	2 stations	39	12	2.84	+0.09	Eureka	6.39	Yankton	0.57
Tennessee	77.3	0.0	Perryville	102	28	Crossville	46	6	4.01	-0.43	Crossville	9.18	Ashwood	0.90
Texas	82.7	-0.2	Clarendon	110	10	Denton	52	4	2.75	+0.14	Honey Grove	9.52	2 stations	0.00
Utah	72.3	+0.8	Hanksville	111	22	Panguitch	30	13	0.95	-0.03	Elkhorn (Fishlake)	4.75	2 stations	0.00
Virginia	74.7	-0.3	Winchester	104	15	Burkes Garden	40	24	4.95	+0.46	Rocky Mount	10.38	Mount Weather	0.99
Washington	66.9	+0.5	Wahluke	112	23	Bumping Lake	32	9	0.33	-0.37	Baker Lake	1.68	12 stations	0.00
West Virginia	72.3	-0.5	2 stations	100	1	2 stations	36	5	5.09	+0.42	Sutton	12.40	Upper Tract	1.65
Wisconsin	67.1	-2.2	Prairie du Chien	99	27	2 stations	32	13	4.26	+0.58	Rhineland	8.16	Cuba	0.44
Wyoming	64.8	-1.0	Basin	102	18	South Pass City	24	1	1.52	+0.06	Colony	4.93	Green River	0.12
Alaska, June	53.4	+1.0	2 stations	85	13	Wonder Lake	24	12	2.90	+0.09	Chignik	19.23	Skagway	0.08
Hawaii	74.5	+0.4	Waiolua Mill	94	15	2 stations	51	18	6.90	+0.93	Olokele (mauka)	32.60	7 stations	0.00
Porto Rico	78.7	-0.1	Canovanas	96	1	Albionito	57	2	10.53	+3.88	Ceparo	20.50	Coamo	3.06

For description of tables and charts, see REVIEW.

Other dates also.

TABLE 1.—Climatological data for Weather Bureau stations, July, 1927

District and station	Elevation of instruments			Pressure			Temperature of the air										Precipitation			Wind					Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month			
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. +	Mean min. -	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Total	Departure from normal	Days with .01 or more	Total movement	Prevailing direction							Maximum velocity		
																															Miles per hour	Direction	Date
New England																																	
Eastport	76	67	85	29.89	29.97	+0.04	58.8	-1.6	88	13	67	45	5	51	39	56	55	89	4.50	+1.1	17	5,587	s.	30	s.	8	4	8	19	7.5	0.0	0.0	
Greenville, Me.	1,070	6		28.83	29.97	+0.04	65.4	-0.4	88	12	75	40	6	55	34	60	59	80	4.02	+0.8	19	5,626	sw.	32	nw.	4	7	8	16		0.0	0.0	
Portland, Me.	103	82	117	29.87	29.99	+0.04	66.8	-1.3	91	13	74	48	5	60	26	62	59	80	3.31	-0.5	14	5,740	s.	33	sw.	13	8	14	9	5.9	0.0	0.0	
Concord	289	70	79	29.67	29.97	+0.01	69.4	+0.9	94	13	80	44	5	59	32	62	59	80	5.27	+1.5	14	3,424	se.	31	w.	13	8	14	9	5.9	0.0	0.0	
Burlington	403	11	48	29.52	29.95	+0.01	68.4	-1.9	89	13	78	49	9	59	31	61	58	81	3.31	-0.5	14	5,740	s.	33	sw.	17	4	10	17	7.1	0.0	0.0	
Northfield	876	12	60	29.98	29.98	+0.04	65.9	0.0	89	13	78	42	9	54	38	61	58	81	3.40	-0.3	14	4,454	s.	30	sw.	14	1	20	10	6.5	0.0	0.0	
Boston	125	115	188	29.84	29.97	+0.01	72.2	+0.5	95	13	80	53	5	64	24	65	62	78	4.77	+1.4	14	6,242	sw.	27	nw.	4	8	14	9	6.0	0.0	0.0	
Nantucket	12	14	90	29.98	30.00	+0.02	67.0	-0.8	81	26	73	55	6	62	19	64	62	90	6.55	+3.9	14	12,219	sw.	48	ne.	1	8	13	10	6.1	0.0	0.0	
Block Island	26	11	46	29.95	29.98	+0.01	68.0	-0.4	80	13	73	56	5	63	15	64	62	88	2.04	-1.3	17	11,469	sw.	46	ne.	1	6	15	10	5.7	0.0	0.0	
Providence	160	215	251	29.82	29.99	+0.02	72.0	-1.4	94	13	80	50	5	64	25	65	62	76	4.16	+0.6	16	7,979	s.	40	nw.	27	7	12	12	6.1	0.0	0.0	
Hartford	159	122		29.81	29.98	+0.01	72.5	+0.9	95	13	81	52	5	64	25	65	62	76	5.01	+0.9	11		s.			8	16	7	5.2	0.0	0.0		
New Haven	106	74	103	29.88	29.99	+0.02	72.4	+0.6	92	12	80	52	5	65	24	65	62	76	5.36	+0.6	11	6,405	sw.	35	ne.	1	8	15	8	5.9	0.0	0.0	
Middle Atlantic States																																	
Albany	97	102	115	29.86	29.96	+0.00	72.5	-0.1	92	14	82	52	5	64	27	66	63	76	2.76	-1.1	15	4,893	s.	29	s.	17	10	15	6	5.1	0.0	0.0	
Binghamton	871	10	94	29.07	29.98	+0.01	70.5	+0.5	95	13	81	43	0	60	35	62	74	3.38	-0.2	15	3,714	e.	22	nw.	4	6	13	12	6.3	0.0	0.0		
New York	314	414	454	29.66	29.99	+0.01	72.9	-0.9	91	13	80	56	5	66	23	66	62	74	5.93	+1.4	11	10,545	s.	45	s.	4	5	16	10	5.9	0.0	0.0	
Harrisburg	374	94	104	29.61	30.00	+0.02	74.2	-0.6	94	13	84	55	5	65	27	66	62	71	3.63	-0.2	13	4,264	sw.	30	nw.	27	4	18	9	6.3	0.0	0.0	
Philadelphia	114	123	184	29.88	30.00	+0.02	75.8	-0.4	93	13	84	59	5	68	23	69	66	74	4.50	+0.2	9	6,217	sw.	30	sw.	7	7	13	11	5.7	0.0	0.0	
Reading	325	81	98	29.64	29.95	+0.01	74.7	-0.5	96	13	84	55	5	66	24	66	61	68	3.82	-0.4	13	3,480	sw.	24	nw.	27	6	15	10	6.0	0.0	0.0	
Scranton	805	111	119	29.15	30.00	+0.02	71.2	+0.5	94	13	81	47	6	61	34	64	60	73	4.48	+0.6	15	4,380	s.	35	s.	21	7	13	11	6.2	0.0	0.0	
Atlantic City	52	37	172	29.94	29.99	+0.01	71.2	-0.9	91	29	76	55	1	66	20	67	64	82	5.30	+1.5	8	12,389	s.	50	s.	7	11	13	7	4.7	0.0	0.0	
Cape May	17	13	49	29.99	29.99	+0.01	72.8	-0.6	92	29	80	52	1	65	30	68	67	89	4.59	0.0	10		sw.			9	15	7		0.0	0.0		
Sandy Hook	22	10	55	29.96	29.98	+0.01	72.8	-0.6	92	29	80	52	1	65	30	68	67	89	4.59	0.0	10		sw.			9	15	7		0.0	0.0		
Trenton	190	159	183	29.79	29.98	+0.01	74.2	-0.9	95	13	83	53	5	65	25	68	65	77	4.40	-0.4	9	7,241	sw.	49	nw.	16	6	15	10	6.1	0.0	0.0	
Baltimore	123	100	215	29.86	29.98	+0.00	77.2	0.0	96	14	86	58	1	69	24	68	63	66	1.41	-3.4	12	6,508	sw.	33	sw.	30	12	8	11	5.5	0.0	0.0	
Washington	112	62	85	29.87	29.99	+0.02	76.4	-0.4	96	14	86	56	5	67	27	69	65	74	1.82	-2.8	9	3,686	sw.	32	nw.	15	8	13	10	5.7	0.0	0.0	
Cape Henry	18	8	54	30.00	30.02	+0.02	76.6	-0.9	96	29	85	55	5	68	26	70	68	79	7.89	+2.0	10	7,535	sw.	42	nw.	30	11	17	3	4.5	0.0	0.0	
Lynchburg	681	153	188	29.30	30.02	+0.01	75.6	-1.9	93	28	86	54	5	65	30	68	65	75	5.90	+1.9	14	3,833	w.	37	w.	29	8	18	5	5.0	0.0	0.0	
Norfolk	91	170	205	29.94	30.04	+0.04	76.8	-1.9	95	28	85	58	1	69	23	69	66	76	6.72	+0.9	11	8,310	s.	43	nw.	7	8	15	8	5.2	0.0	0.0	
Richmond	144	11	52	29.88	30.02	+0.01	76.0	-2.5	94	29	86	56	5	66	25	69	66	78	9.10	+4.7	12	4,929	sw.	40	se.	18	10	14	7	5.1	0.0	0.0	
Wytheville	2,304	49	55	27.72	30.02	+0.01	70.5	-2.1	88	1	81	51	5	60	28	64	62	78	4.47	0.0	14	3,374	w.	25	n.	2	11	13	7	4.6	0.0	0.0	
South Atlantic States																																	
Asheville	2,255	70	84	27.75	30.03	+0.01	72.2	+0.5	89	1	82	56	24	62	26	65	63	82	3.85	-0.9	15	3,983	se.	31	n.	7	6	18	7	5.0	0.0	0.0	
Charlotte	779	55	62	29.21	30.04	+0.03	77.0	+0.1	97	29	89	63	9	68	27	69	67	75	5.52	0.0	16	2,420	sw.	23	w.	28	5	18	8	5.8	0.0	0.0	
Hatteras	11	11	50	30.04	30.04	+0.03	77.0	-1.2	89	28	82	61	6	72	16	72	70	79	3.40	-2.7	9	8,811	sw.	32	sw.	30	13	13	5	4.1	0.0	0.0	
Raleigh	376	103	110	29.64	30.02	+0.00	77.2	-1.6	96	29	87	59	5	68	26	70	68	78	3.91	-2.2	13	4,927	sw.	44	nw.	7	8	12	11	5.6	0.0	0.0	
Wilmington	78	81	91	29.98	30.06	+0.05	77.8	-1.3	93	28	85	59	1	70	21	73	71	83	6.42	-0.6	12	4,838	sw.	21	sw.	29	6	16	9	5.8	0.0	0.0	
Charleston	48	11	62	30.01	30.06	+0.05	78.2	-0.8	100	3	87	68	11	74	25	74	72	80	4.61	-2.6	17	6,188	sw.	32	n.	3	6	13	12	6.1	0.0	0.0	
Columbia, S. C.	351	41	57	29.67	30.05	+0.06	77.9	-1.7	96	28	88	65	19	70	25	71	68	78	6.11	0.0	16	4,100	s.	30	sw.	2	5	17	9	5.9	0.0	0.0	
Due West	711	10	55	29.30	30.06	+0.06	77.9	-1.7	96	28	88	65	19	70	25	71	68	78	6.11	0.0	16	4,100	s.	30	sw.	2	5	17	9	5.9	0.0	0.0	
Greenville, S. C.	1,039	139	146	28.96	30.03	+0.01	77.6	+0.1	97	1	86	61	10	68	29	69	67	78	5.57	0.0	18	4,995	w.	61	w.	1	3	17	11	6.3	0.0	0.0	
Augusta	182	62	77	29.84	30.03	+0.01	77.6	-1.1	100	1	90	64	6	71	26	74	72	82	9.41	+4.1	18	3,198	sw.	39	sw.	11	6	18	7	8.8	0.0	0.0	
Savannah	65	150	194	29.99	30.06	+0.03	80.7	-0.8	99	2	90	68	14	72	28	73	71	81	8.03	+1.8	15	6,738	w.	54	nw.	14	8	12	11	6.1	0.0	0.0	
Jacksonville	43	209	245	30.02	30.07	+0.04	81.2	-0.9	98	2	89	68	18	73	23	74	71	78	6.85	+0.6	20	7,117	sw.	46	sw.	14	8	13	10	5.7	0.0	0.0	
Florida Peninsula																																	
Key West	22	10	64	30.03	30.05	+0.02	84.8	+1.3	94	9	91	74	19	70	19	77	74	73	2.45	-1.1	12	6,532	se.	27	w.	1	10	15	6	5.0	0.0		

TABLE 1.—Climatological data for Weather Bureau stations, July, 1927—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air												Precipitation			Wind				Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. mean min. + 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Total	Departure from normal	Days with .01 or more	Total movement	Prevailing direction	Maximum velocity							
																								Miles per hour	Direction							Date
Ohio Valley and Tennessee	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	%	In.	In.	Miles					0-10	In.	In.			
							75.6	-0.8										68	3.88	-0.1						5.0					
Chattanooga	762	189	213	29.22	30.01	-.01	78.4	0.0	95	28	88	62	24	68	28	68	65	70	5.01	+1.1	11	4,441	sw.	39	nw.	2	9	20	5.1	0.0	0.0
Knoxville	905	102	111	29.00	30.03	+.01	77.9	+0.8	95	1	88	60	24	68	28	69	65	72	3.41	-0.8	10	4,112	sw.	38	nw.	7	9	18	4.7	0.0	0.0
Memphis	399	76	97	29.59	30.01	+.01	79.9	-0.8	96	11	88	65	24	72	23	70	66	64	1.58	-1.9	8	5,188	sw.	34	w.	30	18	7	6.3	0.0	0.0
Nashville	546	168	191	29.46	30.03	+.02	78.4	-0.7	95	28	88	60	5	68	27	69	64	67	1.59	-2.8	6	4,863	w.	35	nw.	15	14	12	5.6	0.0	0.0
Lexington	989	193	230	29.38	30.02	+.01	75.2	-0.7	95	28	84	55	5	66	27	67	63	66	2.95	-1.5	12	8,322	sw.	37	sw.	14	13	15	3.2	0.0	0.0
Louisville	525	188	234	29.45	30.02	+.02	76.4	-2.2	95	1	86	56	4	67	27	67	63	66	4.27	+0.5	8	6,602	sw.	56	sw.	28	12	13	6.4	0.0	0.0
Evansville	431	76	116	29.57	30.03	+.03	77.8	-0.9	96	1	87	55	4	68	25	68	64	65	3.62	-0.2	9	5,437	sw.	37	sw.	7	15	12	4.1	0.0	0.0
Indianapolis	822	194	230	29.14	30.01	+.02	74.2	-1.5	95	28	84	50	4	64	23	65	59	62	3.48	-0.6	9	7,163	sw.	44	w.	7	9	18	4.5	0.0	0.0
Royal Center	736	11	55	29.22	30.00	---	71.2	---	96	28	82	49	4	60	31	---	---	---	3.46	---	12	6,312	sw.	41	nw.	1	6	18	7.3	0.0	0.0
Terre Haute	575	96	129	29.39	30.00	---	75.2	---	97	28	85	51	4	65	29	66	62	67	1.90	---	8	5,929	sw.	35	nw.	6	11	12	8.1	0.0	0.0
Cincinnati	627	11	51	29.35	30.01	+.01	75.5	+0.4	95	28	86	55	5	65	28	66	62	69	3.09	-0.4	12	4,258	sw.	25	nw.	14	15	12	4.3	0.0	0.0
Columbus	822	179	222	29.16	30.01	+.01	73.7	-1.2	94	1	83	52	4	64	25	66	62	71	3.86	+0.2	12	5,996	s.	46	nw.	14	11	12	8.4	0.0	0.0
Dayton	869	137	173	29.07	30.00	---	74.8	-0.6	96	1	85	54	5	65	30	65	60	65	3.37	+0.1	11	5,564	sw.	33	nw.	14	7	20	4.5	0.0	0.0
Elkins	1,947	59	67	28.04	30.03	+.02	68.4	-1.9	87	13	80	41	5	57	35	62	60	80	7.35	+2.7	12	3,011	w.	36	w.	7	4	18	9.6	0.0	0.0
Parkersburg	637	77	82	29.38	30.03	+.02	74.4	-1.0	94	13	85	51	5	63	30	66	62	72	4.45	-0.2	13	3,434	se.	27	nw.	2	9	9	13.6	0.0	0.0
Pittsburgh	842	353	410	29.11	30.00	---	73.0	-1.6	92	1	82	50	4	64	25	64	60	67	6.34	+1.9	13	6,964	sw.	44	sw.	14	7	12	6.1	0.0	0.0
Lower Lake Region							70.4	-1.1										70	4.06	+0.7								4.9			
Buffalo	767	247	280	29.15	29.96	-.01	68.2	-1.6	90	1	76	46	4	61	25	63	60	77	5.50	+2.4	13	9,738	sw.	72	sw.	7	10	10	11.5	0.0	0.0
Canton	448	10	61	29.48	29.94	---	67.4	-3.1	87	13	77	46	5	58	32	---	---	---	3.94	+0.7	17	5,107	sw.	30	w.	13	10	9	4.0	0.0	0.0
Oswego	335	76	91	29.96	---	---	67.6	-2.8	91	13	75	52	4	61	25	---	---	---	3.26	-0.1	12	5,894	s.	25	nw.	4	11	9	11.1	0.0	0.0
Rochester	523	86	102	29.41	29.97	---	70.3	-0.4	94	13	79	48	4	62	27	63	59	70	3.25	+0.2	17	5,713	w.	30	w.	17	10	10	11.7	0.0	0.0
Syracuse	597	97	113	29.35	29.99	+.02	69.4	-1.4	93	13	78	48	4	61	25	---	---	---	4.88	+1.2	15	5,732	s.	48	sw.	17	9	11	11.7	0.0	0.0
Erie	714	130	166	29.23	29.98	---	70.6	-0.4	93	13	78	52	5	63	24	64	60	69	4.83	+1.6	15	4,648	nw.	18	se.	6	11	15	5.4	0.0	0.0
Cleveland	762	190	201	29.19	29.96	---	71.6	+0.2	94	13	79	54	5	64	25	63	59	67	3.11	-0.4	12	7,793	n.	33	se.	3	10	15	6.5	0.0	0.0
Sandusky	629	5	67	29.32	30.00	+.01	72.9	-0.5	97	13	82	52	5	64	26	64	29	67	5.65	+1.9	12	5,554	sw.	29	s.	21	5	17	9.6	0.0	0.0
Toledo	628	203	243	29.33	30.00	+.01	72.5	-0.7	94	13	82	52	20	64	26	64	60	68	2.48	-0.8	13	8,666	sw.	59	sw.	7	17	10	4.3	0.0	0.0
Fort Wayne	856	113	124	29.09	30.00	---	72.5	-1.0	95	1	83	54	4	62	29	64	59	66	2.91	---	13	5,590	sw.	38	nw.	6	14	14	3.4	0.0	0.0
Detroit	730	218	258	29.22	30.00	+.02	71.6	-0.5	93	28	80	53	4	63	24	63	58	65	3.59	+0.1	12	6,332	e.	42	nw.	12	9	13	5.4	0.0	0.0
Upper Lake Region							66.3	-1.6										72	3.61	+0.5								4.7			
Alpena	609	13	92	29.34	30.00	+.03	64.8	-1.1	87	13	75	42	4	55	31	59	56	73	1.86	-1.2	10	7,978	nw.	42	nw.	2	15	13	3.4	0.0	0.0
Escanaba	612	54	60	29.34	29.99	+.02	63.2	-2.8	86	28	72	43	4	55	29	58	55	74	4.33	+1.0	13	6,662	s.	35	n.	28	9	16	6.9	0.0	0.0
Grand Haven	632	54	89	29.32	29.98	---	66.9	-1.8	91	1	75	44	4	58	25	61	57	71	2.33	-0.2	11	6,916	w.	36	sw.	12	14	10	7.4	0.0	0.0
Grand Rapids	707	70	87	29.24	29.99	+.01	71.2	-1.1	97	1	82	47	4	61	29	61	55	61	1.43	-1.2	10	3,987	nw.	32	nw.	11	9	14	8.3	0.0	0.0
Houghton	668	64	99	29.27	29.99	+.03	61.9	-3.6	89	1	71	46	3	52	25	---	---	---	7.98	+4.9	14	8,396	w.	34	n.	16	5	18	8.9	0.0	0.0
Lansing	878	11	62	29.07	29.99	---	69.4	-1.5	96	1	81	44	4	57	32	63	59	71	2.11	-1.1	12	3,172	nw.	21	nw.	11	14	12	5.2	0.0	0.0
Ludington	637	60	66	29.30	29.99	---	64.2	---	82	1	72	43	4	56	24	60	57	77	2.36	---	12	6,139	s.	34	sw.	11	20	7	4.1	0.0	0.0
Marquette	734	77	111	29.20	29.99	+.04	63.0	-1.9	91	1	72	46	3	54	29	59	56	78	6.15	+3.0	14	6,006	nw.	46	w.	1	5	14	12.3	0.0	0.0
Port Huron	638	70	120	29.30	29.99	+.01	68.2	-0.6	91	1	77	48	4	59	26	62	58	72	4.99	+2.2	12	6,829	sw.	46	w.	12	14	16	1.9	0.0	0.0
Sault Sainte Marie	614	11	52	29.31	30.00	+.03	62.4	-1.4	92	1	78	44	20	52	29	57	53	76	2.57	-0.2	10	5,211	nw.	35	nw.	17	13	14	4.5	0.0	0.0
Chicago	673	7	131	29.28	30.00	+.02	71.7	-0.8	95	28	79	56	3																		

TABLE 1.—Climatological data for Weather Bureau stations, July, 1927—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air										Precipitation			Wind					Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month		
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. + 2	Departure from normal	Maximum	Date	Mean minimum	Date	Mean maximum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Total	Departure from normal	Days with .01, or more	Total movement	Prevailing direction	Maximum velocity									
																							Miles per hour	Direction							Date	
Northern Slope																																
Billings	3,140	5					68.6	101	9	85	42	1	52	47	58	52	62	1.51		7		nw.			17	5	9	0.0	0.0	0.0		
Havre	2,505	11	44	27.41	30.01	-.10	68.6	101	9	85	42	1	52	47	58	52	62	1.51	1.0	13	3,826	e.	38	sw.	25	15	15	1.3	0.0	0.0		
Helena	4,110	87	112	25.38	29.99	-.06	67.4	92	8	81	40	1	54	39	55	47	55	1.08	0.0	6	5,916	sw.	36	sw.	4	16	7	4.1	0.0	0.0		
Kalispell	2,973	48	56	26.97	29.97	-.04	65.2	91	23	79	43	1	51	37	53	44	56	0.77	-0.1	7	4,358	nw.	26	w.	9	20	9	2.3	0.0	0.0		
Miles City	2,371	48	55	27.52	30.02	-.10	71.6	98	9	84	52	6	59	37	60	52	55	1.32	0.0	10	4,243	ne.	60	nw.	19	15	13	3.6	0.0	0.0		
Rapid City	3,259	50	58	26.70	30.03	-.13	68.2	90	20	79	46	2	57	36	59	54	62	2.75	+0.2	12	5,463	w.	47	n.	20	8	16	4.7	0.0	0.0		
Cheyenne	6,088	84	101	24.17	30.03	-.11	64.9	87	20	77	44	1	53	36	53	47	60	2.66	+0.7	17	7,110	s.	44	nw.	11	12	8	5.0	0.0	0.0		
Lander	5,372	60	68	24.77	30.01	-.09	67.6	93	19	83	44	16	53	41	52	47	60	4.37	-0.5	6	3,948	sw.	42	sw.	2	12	14	4.2	0.0	0.0		
Sheridan	3,790	10	47	26.18	30.02	-.09	65.8	93	9	80	44	6	52	42	58	53	67	0.92		9	3,016	nw.	27	nw.	27	14	13	4.1	0.0	0.0		
Yellowstone Park	6,241	11	48	24.02	30.03	-.11	60.8	87	18	76	33	16	45	42	48	40	55	0.42	-0.8	8	6,063	s.	35	s.	2	14	16	1.9	0.0	0.0		
North Platte	2,821	11	51	27.15	30.02	-.09	73.8	97	8	87	50	17	61	39	62	56	60	0.43	-2.2	9	4,874	se.	31	ne.	8	10	6	3.6	0.0	0.0		
Middle Slope																																
Denver	5,292	106	113	24.88	30.03	-.12	71.2	105	17	83	54	1	59	39	57	49	55	2.36	+0.7	9	5,027	s.	35	nw.	28	10	14	7.4	0.0	0.0		
Pueblo	4,685	80	86	25.41	30.01	-.10	74.0	96	17	88	53	1	60	40	58	51	56	1.86	-0.1	11	4,995	e.	37	s.	8	13	14	4.5	0.0	0.0		
Concordia	1,392	50	58	28.56	30.00	+.05	76.5	102	6	87	57	2	66	34	65	60	60	4.27	+0.6	7	4,663	s.	32	sw.	28	16	10	6.3	0.0	0.0		
Dodge City	2,509	11	51	27.47	30.01	-.08	77.3	100	18	90	58	1	65	32	65	59	60	4.19	+0.8	9	6,303	se.	40	se.	26	20	8	3.1	0.0	0.0		
Wichita	1,358	139	158	28.59	29.98	+.02	78.0	101	16	88	61	1	68	29	68	64	66	3.55	+0.2	9	7,527	s.	42	n.	28	15	12	4.1	0.0	0.0		
Broken Arrow	765	11	56	29.20	30.02	-.07	77.7	96	10	87	60	24	68	28				5.44		10	6,876	s.	41	nw.	18	16	7	4.3	0.0	0.0		
Oklahoma City	1,214	10	47	28.74	29.99	+.03	80.0	100	10	90	61	24	70	28	70	66	68	3.31	-0.3	8	6,239	s.	42	sw.	31	14	10	7.4	0.0	0.0		
Southern Slope																																
Abilene	1,738	10	52	28.21	29.97	+.04	83.1	101	20	95	65	3	71	30	69	63	59	1.89	-0.5	7	6,061	s.	33	sw.	12	12	12	7.4	0.0	0.0		
Amarillo	3,676	10	49	26.36	30.00	+.03	78.2	103	20	91	57	3	66	34	64	57	57	1.68	-1.5	11	6,579	s.	27	s.	28	16	8	7.4	0.0	0.0		
Del Rio	944	64	71	28.97	29.93	+.03	84.6	103	19	94	67	14	75	29	72	66	61	1.67	-0.6	9	6,613	se.	37	n.	14	15	13	3.4	0.0	0.0		
Roswell	3,566	75	85	26.42	29.94	+.06	79.0	100	20	92	59	2	66	35	63	54	51	1.13	-1.0	9	5,378	s.	39	ne.	12	17	14	0.3	0.0	0.0		
Southern Plateau																																
El Paso	3,778	132	175	26.21	29.88	+.04	83.0	102	15	95	64	24	72	31	64	52	42	2.52	+0.4	6	6,818	e.	37	ne.	15	18	12	1.3	0.0	0.0		
Santa Fe	7,013	338	53	23.42	29.92	+.04	70.4	102	16	82	51	1	58	31	55	47	51	1.06	-1.6	8	4,267	se.	23	se.	8	8	20	3.1	0.0	0.0		
Flagstaff	6,907	10	59	23.50	29.91	+.08	66.4	89	17	82	40	1	51	42	52		55	2.39		13	5,050	nw.	35	ne.	17	10	16	5.0	0.0	0.0		
Phoenix	1,108	10	82	28.69	29.80	+.02	91.3	112	21	105	65	1	78	40	69	56	37	0.24	-0.8	2	4,070	w.	34	s.	3	14	17	0.3	0.0	0.0		
Yuma	141	9	54	29.66	29.80	+.04	91.8	114	17	106	67	1	77	41	73	65	49	0.18	+0.1	2	3,734	sw.	29	se.	18	24	6	1.6	0.0	0.0		
Independence	3,957	5	25	25.96	29.90	+.07	78.5	103	13	97	48	4	60	45	56			0.10	0.0	1		nw.			19	9	3	2.6	0.0	0.0		
Middle Plateau																																
Reno	4,532	74	81	25.52	29.92	+.05	72.2	102	12	90	45	4	54	47	52	37	35	0.13	-0.2	3	5,214	w.	33	se.	22	26	5	0.1	0.0	0.0		
Tonopah	6,090	12	20				75.1	97	12	87	57	4	63	29	33	25	0.05		1		se.											
Winnemucca	4,344	18	56	25.64	29.95	+.05	72.4	102	12	90	45	4	54	47	52	37	35	0.13	-0.2	3	5,214	se.	33	se.	22	26	5	0.1	0.0	0.0		
Modena	5,478	10	43	24.69	29.91	+.05	71.9	101	13	95	18	88	46	1	56	41	53	38	30	1.17	-0.1	7	8,130	sw.	47	sw.	2	19	10	2.0	0.0	0.0
Salt Lake City	4,360	163	203	25.65	29.92	+.02	78.2	100	18	90	52	5	66	32	57	43	33	0.22	-0.3	2	5,607	s.	42	e.	23	18	11	2.9	0.0	0.0		
Grand Junction	4,602	60	68	25.45	29.97	+.08	77.2	105	17	90	57	5	64	35	59	48	43	0.58	+0.1	9	4,582	se.	39	se.	3	15	14	2.3	0.0	0.0		
Northern Plateau																																
Baker	3,471	48	53	26.50	30.01	+.06	66.5	109	23	82	39	5	50	40	53	41	45	0.10	-0.3	2	4,059	se.	23	sw.	31	20	8	3.2	0.0	0.0		
Boise	2,739	78	86	27.15	29.94	+.01	74.8	109	23	81	46	5	59	39	56	42	37	0.2	-0.2	0	3,441	nw.	30	w.	26	24	5	2.1	0.0	0.0		
Lewiston	757	40	48	29.18	29.97	+.02	75.2	106	24	92	50	1	59	43				0.46	0.0	3	2,295	e.	24	ne.	31	21	9	1.2	0.0	0.0		
Pocatello	4,477	00	68	25.52	29.92	+.00	73.6	108	18	89	42	5	58	42	53	38	34	0.64	0.0	2	6,066	s.	33	sw.	3	14	16	1.3	0.0	0.0		
Spokane	1,920	101	110	27.07	29.98	+.03	71.4	100	24	86	50	5	57	37	56	44	43	0.55	-0.1	3	3,974	s.	36	n.	30	17	11	3.0	0.0	0.0		
Walla Walla	991	57	65	28.02	29.97	+.00	76.6	105	23	90	54	5	64																			
North Pacific Coast Region																																
North Head	211	11	56	29.90	30.13	+.05	57.4	102	6	88	23	60	51	28	54	16	55	53	0.25	-0.4	7	10,074	n.	37	n.	20	2	5	24	8.6	0.0	0.0
Port Angeles	29	8	53	30.09	30.12		58.9		88	23	67	45	27	50	33				0.11	-0.3	3	4,046	nw.	19	w.	7	14	7	10.4	0.0	0.0	
Seattle	125	215	250	29.95	30.08	+.04	65.2	91	23	75	33	50	30	56	32	57	51	66	0.10	-0.5	2	4,717	nw.	34	sw.	11	12	14	5.4	0.0	0.0	
Tacoma	194	172	201	29.89	30.09	+.03	65.1	91	23	75	33	50	10	55	33				0.03	-0.6	2	5,420	n.	39	sw.	16	10	13	8.1	0.0	0.0	
Tatoosh Island	86	9	53	30.01	30.11	+.06	54.8	83	6	67	23	58	47	16	52	15	53	94	0.71	-1.1	11	7,163	s.	34	s.	24	4	11	16.7	0.0	0.0	
Yakima	1,071	5					73.2		102	23	90	44	5	56	44	58			0.49		1		nw.			19	10	2	2.8	0.0	0.0	
Medford	1,425	4					71.9		104	23	91	43	5	53	46	58	49	53	0.34		1		nw.			24	6	1		0.0	0.0	
Portland, Oreg.	153	68	106	29.91	30.07	+.02	68.2	101	23	79	53	10	58	34	59	54	63	0.95	+0.3	2	4,422	nw.	19	nw.	22	13	12	6.4	0.0	0.0		
Roseburg	510	9	57	29.52	30.06	+.03	68.6	101	8	98	23	82	47	5	54	38	58	50	0.7	-0.3	0	3,722	n.	20	n.	21	23	7	1	2.3	0.0	0.0
Middle Pacific Coast Region																																
Eureka	62	73	89	30.02	30.09	+.04	55.6	101	62	24	59	48	28																			

TABLE 2.—Data furnished by the Canadian Meteorological Service, July, 1927

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. + 2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	Inches	Inches	Inches	° F.	° F.	° F.	° F.	° F.	° F.	Inches	Inches	Inches
St. Johns, N. F.	125												
Sydney, C. B. I.	48	29.98	30.03	+0.10	65.8	+3.5	74.9	56.8	85	41	4.18	+0.53	0.0
Halifax, N. S.	88	29.79	29.89	— .07	63.2	— 0.2	70.6	55.9	82	49	5.19	+1.14	0.0
Yarmouth, N. S.	65	29.88	29.95	— .00	61.2	+1.7	67.9	54.4	79	43	5.13	+1.66	0.0
Charlottetown, P. E. I.	38	29.92	29.96	+ .06	67.6	+3.5	74.5	60.7	83	50	3.52	+0.03	0.0
Chatham, N. B.	28	29.84	29.87	— .01	66.4	+1.4	77.0	55.9	87	41	5.41	+1.22	0.0
Father Point, Que.	20												
Quebec, Que.	206	29.62	29.94	+ .03	67.6	+2.1	76.4	58.8	88	46	7.36	+3.10	0.0
Montreal, Que.	187	29.71	29.91	— .02	69.1	+0.6	77.5	60.8	85	47	3.94	— 0.35	0.0
Stonecliffe, Ont.	489												
Ottawa, Ont.	236	29.68	29.94	.00	68.2	— 1.3	78.2	58.1	87	47	5.18	+1.71	0.0
Kingston, Ont.	285												
Toronto, Ont.	379	29.55	29.94	— .03	68.8	+0.8	78.3	59.3	91	47	5.87	+2.95	0.0
Cochrane, Ont.	930												
White River, Ont.	1,244	28.65	29.94	.00	58.9	— 0.6	73.8	44.1	90	32	6.54	+3.74	0.0
Port Stanley, Ont.	592												
Southampton, Ont.	656	29.28	29.90	+ .02	63.7	— 1.0	73.0	54.5	86	44	3.58	+1.60	0.0
Parry Sound, Ont.	688	29.27	29.95	— .01	65.4	— 0.6	74.7	56.2	91	42	2.47	— 0.15	0.0
Port Arthur, Ont.	644												
Winnipeg, Man.	760	29.16	29.98	+ .05	65.5	— 0.5	76.7	54.3	90	42	1.14	— 1.94	0.0
Minnedosa, Man.	1,690												
Le Pas, Man.	860				63.0		75.1	50.9	93	35	2.04		0.0
Qu'Appelle, Sask.	2,115	27.75	29.96	+ .04	62.4	— 1.1	73.3	51.5	88	38	5.87	+3.39	0.0
Medicine Hat, Alb.	2,144	27.71	29.92	+ .02	68.5	+0.7	81.1	55.9	95	45	5.43	+3.34	0.0
Moose Jaw, Sask.	1,759				65.5		78.1	52.9	94	40	2.16		0.0
Swift Current, Sask.	2,392	27.46	29.94	+ .03	65.3	— 1.2	78.8	51.9	92	43	3.47	+1.03	0.0
Calgary, Alb.	3,428	26.54	30.07	+ .17	59.9	— 0.7	72.1	47.7	85	40	9.66	+0.98	0.0
Banff, Alb.	4,521	25.51	30.03	+ .13	56.9	+0.3	70.8	43.1	89	34	2.96	— 0.28	0.0
Edmonton, Alb.	2,150	27.72	29.97	+ .07	61.4	+0.8	72.3	50.5	88	38	4.25	+1.22	0.0
Prince Albert, Sask.	1,450	28.46	30.01	+ .10	64.0	+2.1	75.0	53.0	90	43	3.81	+1.76	0.0
Battleford, Sask.	1,592	28.28	29.99	+ .09	64.5	— 0.2	75.8	53.2	91	39	3.94	+1.60	0.0
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.83	30.08	+ .03	59.9	— 0.1	67.5	52.2	89	50	0.21	— 0.19	0.0
Barkerville, B. C.	4,180												
Triangle Island, B. C.	680												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151												

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Sydney, C. B. I.	48	29.90	29.95	— .00	53.9	— 1.5	64.3	43.5	81	36	3.30	+0.07	0.0
Halifax, N. S.	88	29.71	29.81	— .14	55.0	— 2.7	63.9	46.1	74	38	14.14	+10.38	0.0
Yarmouth, N. S.	65	29.84	29.91	— .04	54.4	— 0.6	62.4	46.4	79	37	1.30	— 1.63	0.0
Charlottetown, P. E. I.	38	29.86	29.90	— .02	56.7	— 0.7	64.6	48.7	76	39	1.30	— 1.37	0.0
Chatham, N. B.	28	29.81	29.84	— .05	55.9	— 4.1	67.4	44.3	83	32	4.56	+1.10	0.0
Father Point, Que.	20	29.86	29.88	+ .01	52.7	— 0.3	61.5	43.9	73	32	1.16	— 1.82	0.0
Medicine Hat, Alb.	2,144	27.57	29.78	— .07	62.8	+0.8	75.0	50.6	89	39	1.31	— 1.45	0.0
Calgary, Alb.	3,428	26.41	29.94	+ .10	56.0	0.0	68.5	43.6	81	33	4.40	+1.95	0.0
Banff, Alb.	4,521	25.37	29.88	+ .04	52.6	+1.1	65.4	39.7	80	29	1.74	— 1.59	0.0
Edmonton, Alb.	2,150	27.58	29.83	— .01	57.5	+0.6	68.5	46.5	81	35	3.10	+0.24	0.0
Kamloops, B. C.	1,262	28.65	29.91	+ .04	66.7	+2.9	78.9	54.6	93	43	2.97	+1.55	0.0
Victoria, B. C.	230	29.75	30.00	— .01	57.8	+1.5	65.0	50.6	82	47	0.84	— 0.36	0.0
Barkerville, B. C.	4,180	25.66	29.93	+ .06	51.3	+0.6	61.9	40.8	77	34	4.11	+0.63	0.0
Prince Rupert, B. C.	170				54.8		63.1	46.5	78	40	2.91		0.0
Hamilton, Ber.	151	29.95	30.11	— .01	75.1	+0.1	81.8	68.5	87	61	7.84	+1.89	0.0

(Plotted by Wilfred P. Day)

Center of Low Pressure, July, 1927. (Inset) Departure of Monthly Mean Pressure from Normal (Plotted by Wilfred P. Day)

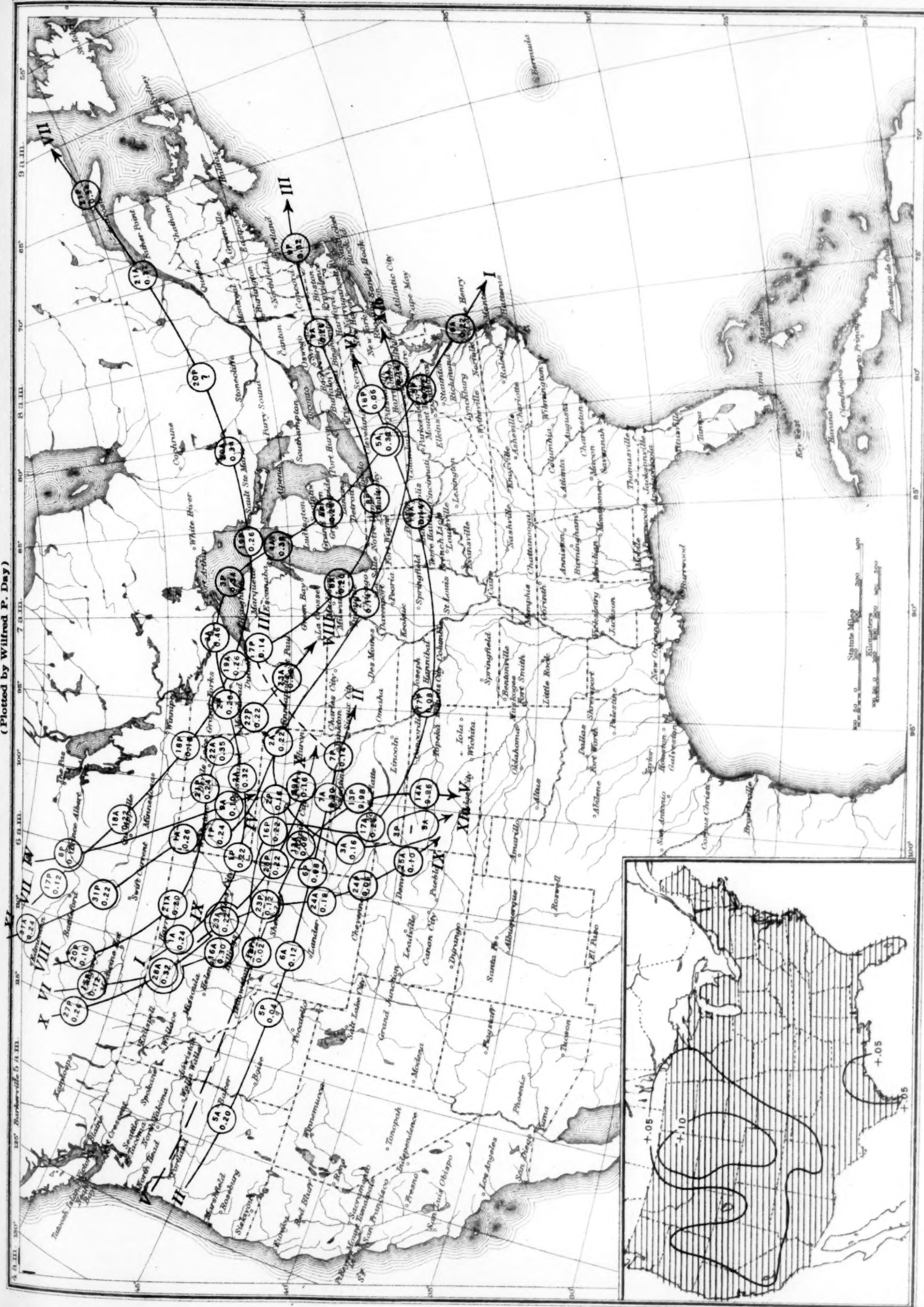


Chart II. Tracks of Centers of Cyclones, July, 1927. (Inset) Change in Mean Pressure from Preceding Month
(Plotted by Wilfred P. Day)

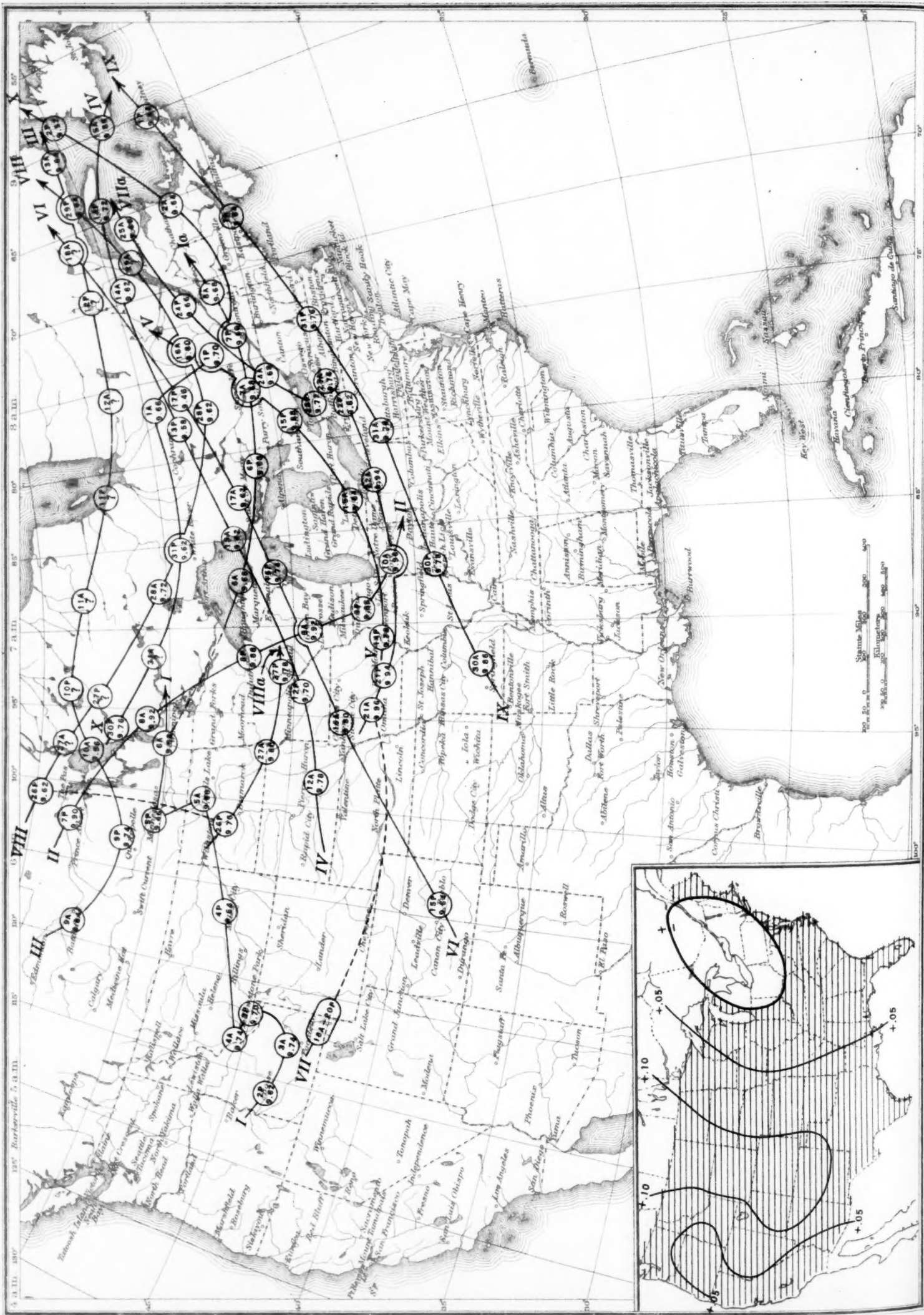


Chart III. Departure (°F.) of the Mean Temperature from the Normal, July, 1927

Chart III. Departure (°F.) of the Mean Temperature from the Normal, July, 1927

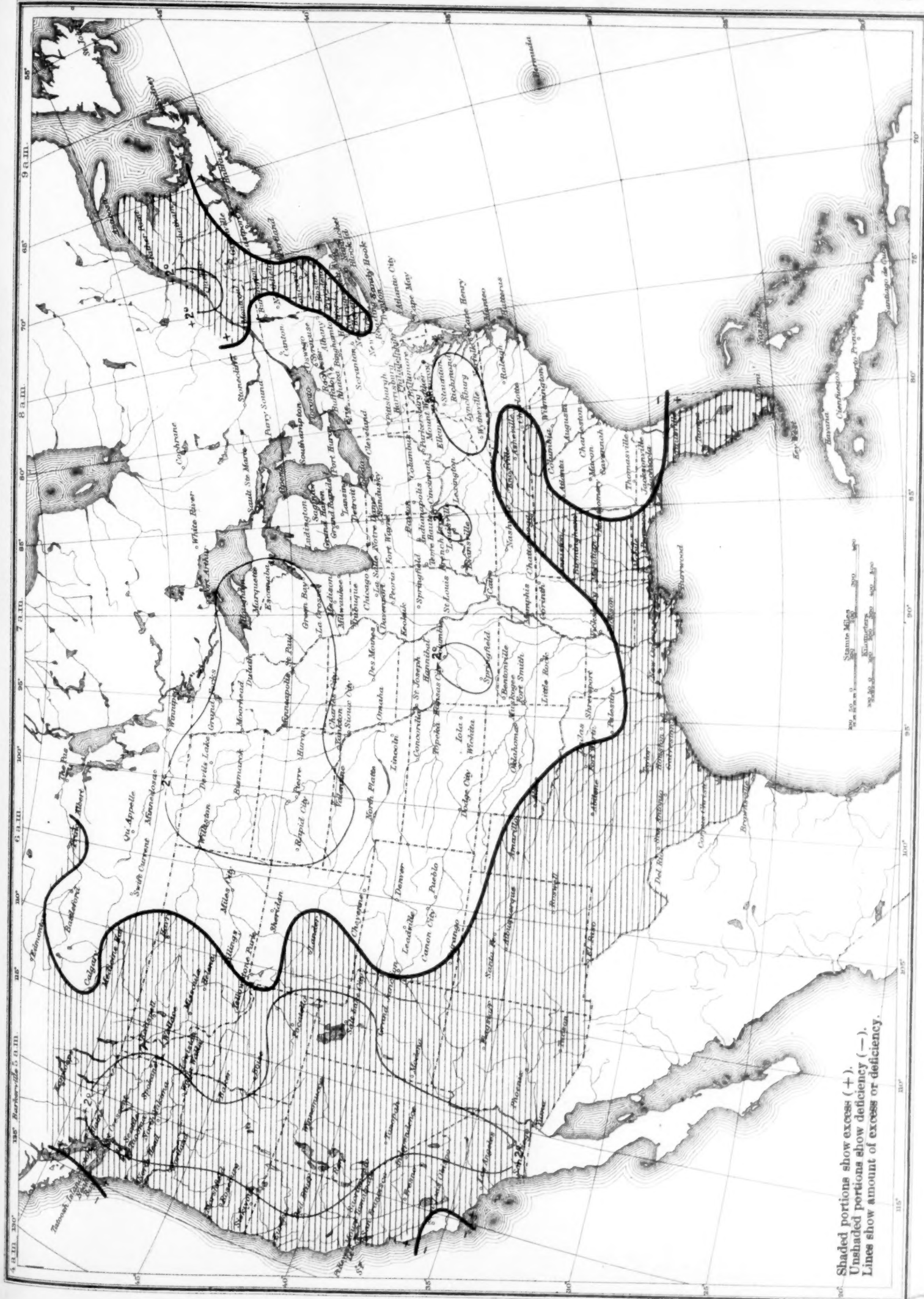


Chart IV. Total Precipitation, Inches, July, 1927. (Inset) Departure of Precipitation from Normal

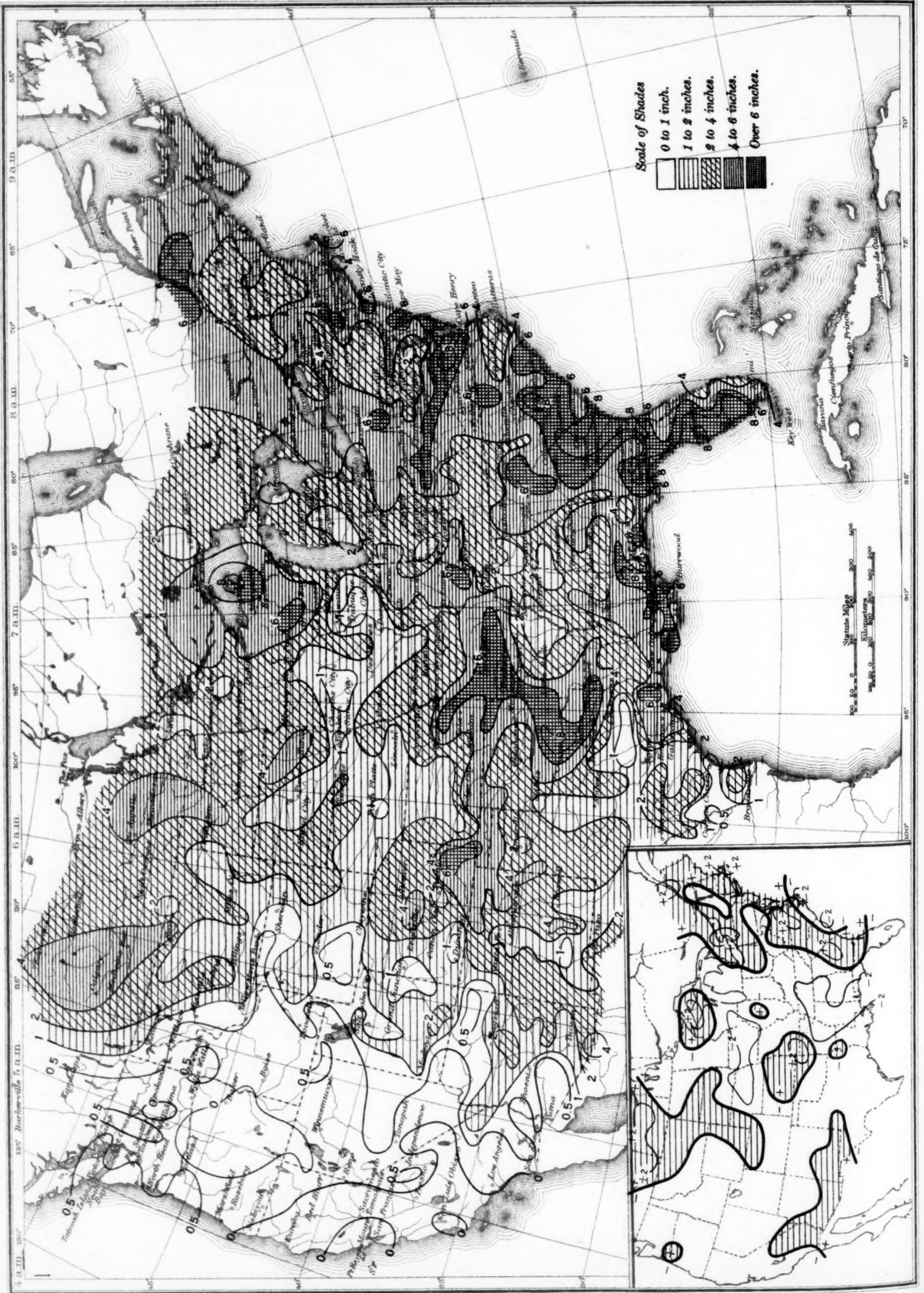


Chart V. Percentage of Clear Sky between Sunrise and Sunset, July, 1927



Chart V. Percentage of Clear Sky between Sunrise and Sunset, July, 1927

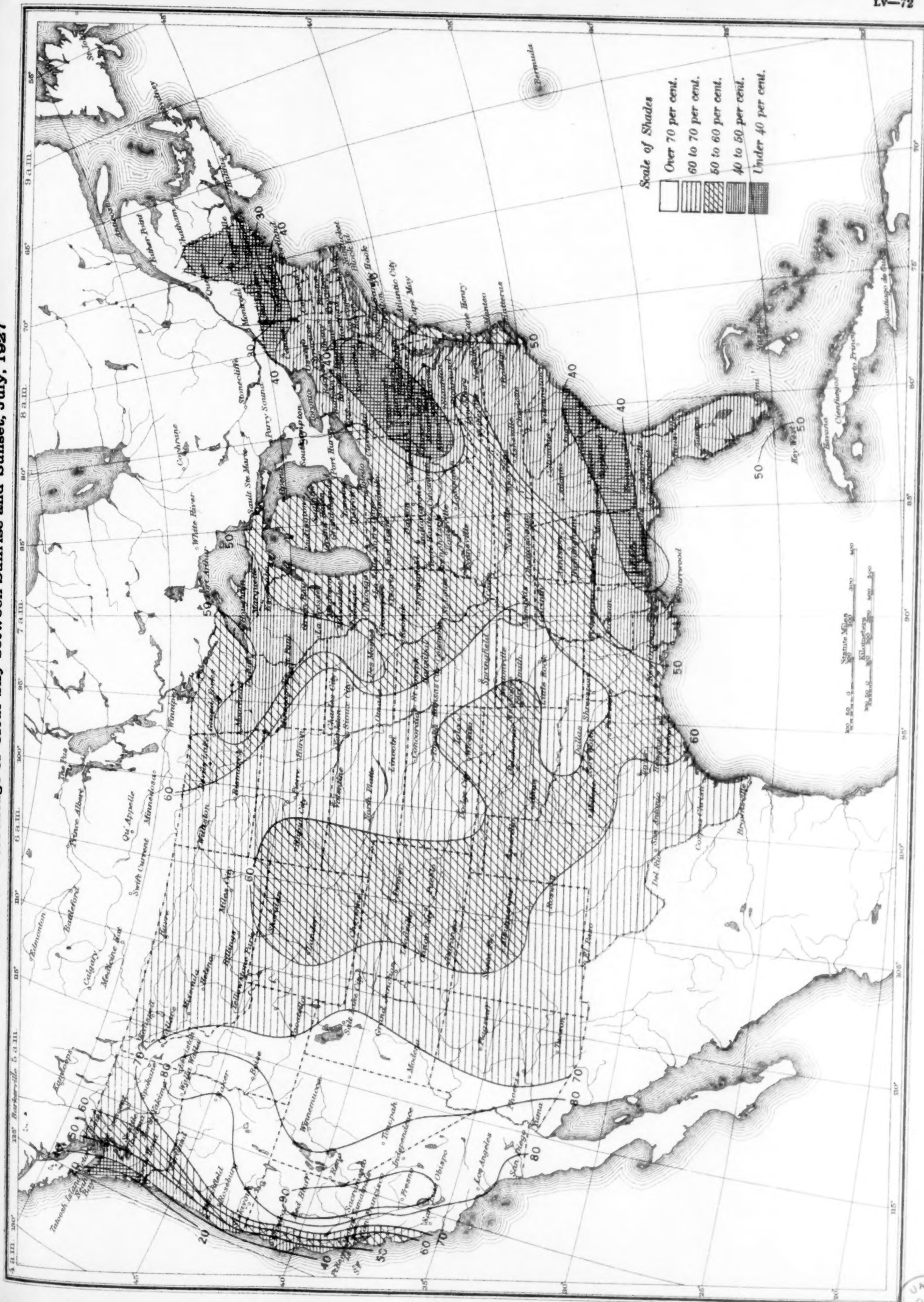


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, July, 1927

